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VOL. 85 NO. 4 OCTOBER 1957

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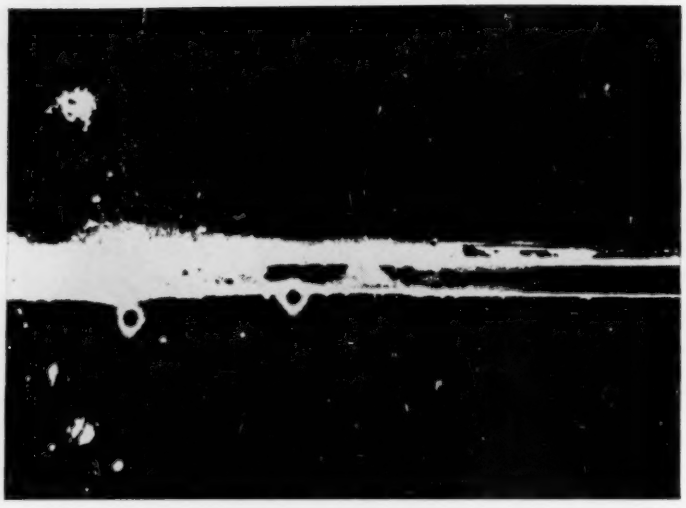

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VOL. 85 OCTOBER 1957 NO. 4

Controlling the Digital Computer . . . . . *R. W. Hamming* 169

Ovigenic-Ovisorptive Cycle in the Economy of the Honey Bee . . . . *S. E. Flanders* 176

Karst Landscapes of Cuba, Puerto Rico, and Jamaica . . *A. H. Doerr and D. R. Hoy* 178

Concept of Energy in Mechanics . . . . . *R. B. Lindsay* 188

Control of Screw-worm Fly by Atomic Radiation . . . . . *E. F. Knipling* 195

Book Reviews of *Rockets, Missiles and Space Travel; Medical Department, United States Army, Surgery in World War II, General Surgery; Quest for a Continent; Operation Deepfreeze; Natural History of Birds; Family Medical Costs and Voluntary Health Insurance: a Nationwide Survey; 1001 Questions Answered about the Seashore; Nuclear Weapons and Foreign Policy; Archaeology in the U.S.S.R.; Light, Vegetation and Chlorophyll; The Fight for Fluoridation; Follow the Whale; The Language of Modern Physics; A History of Mechanics; About Earthquakes; The Amateur Astronomer; A Key to the Stars*; Books Reviewed in *Science*; New Books 203

Association Affairs: AAAS Indianapolis Meetings, 1871–1937; Election of AAAS Officers; AAAS Finances: Report for 1956 215

Cover: Aristotle's Lantern

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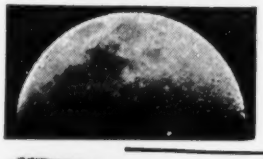

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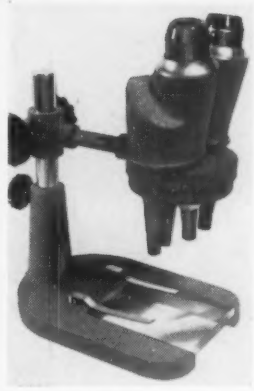

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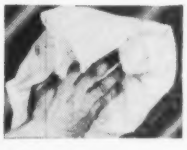

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Shown at Bell Laboratories, Murray Hill, N. J., are, left to right, F. J. Herr, S. T. Brewer, L. R. Snoke, E. E. Zajac and F. W. Kinsman.

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F. J. Herr, M.S., Stevens Institute, is concerned with systems design and analysis. He studies the feasibility of new approaches and carries out analysis programs to select optimum parameters for a proposed system design.

S. T. Brewer, M.S. in E.E., Purdue, communications and electronics engineer, explores new designs for sea-bottom amplifiers needed to step up power of hundreds of simultaneous telephone conversations.

L. R. Snoke, B.S. in Forestry, Penn State, is the team biologist. He investigates the resistance of materials to chemical and microbiological attack in sea water. Materials are evaluated both in the laboratory and in the ocean.

E. E. Zajac, Ph.D. in Engineering Mechanics, Stanford, is a mathematician. He studies the kinematics of cable laying and recovery. Cable's dynamic characteristics, ship's motion, the mountains and valleys in the ocean bottom — all must be taken into account.

F. W. Kinsman, Ph.D. in Engineering, Cornell, solves the shipboard problems of storage, handling and "overboarding" of cable. New machinery for laying cable is being developed.

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THE
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OCTOBER 1957

Controlling the Digital Computer

R. W. HAMMING

Dr. Hamming received his training at the University of Chicago, the University of Nebraska, and the University of Illinois. He first used large-scale computing equipment at Los Alamos, New Mexico, during World War II. Since 1946 he has been connected with Bell Telephone Laboratories, where he is a member of the mathematical research department. He is vice president of the Association for Computing Machinery. This article is based on an address that he delivered 26 December 1956 at the AAAS meetings in New York.

THERE appears to be a mysterious aura surrounding computers today, something that prevents people from seeing them in a reasonable perspective. Modern advertising may be somewhat to blame, but it seems to me that much of the responsibility rests on the computer experts themselves, since they often make great claims without revealing how these claims are to be realized. In order to compensate for this tendency, I propose to describe what modern, general-purpose, digital computers can be expected to do, how to control these machines to get them to do what you want, and some of the current problems involved in harnessing these new tools (*1*).

The simplest approach seems to be to view a computing machine as if it were merely another tool that human beings have invented, to be used for their own benefit. The meaning in which I am using the word *tool* is as a device for extending man's abilities. Some tools extend the senses, as a microscope extends the visual range. Other tools, such as a hammer, extend muscle power. In one way, a computer may be said to extend mental power, which is, perhaps, what gives it so much glamor.

The typical digital computer adds, subtracts, multiplies, and divides, much as a person does with paper and pencil. The machine can also choose between two alternative routines, depending on some number in making the choice. For example, if the selected number is negative, the machine will compute one thing—say the sine of x—while if the number is positive or zero, it will compute another —say the cosine of x. In principle, there is nothing a digital computer can do that you or I cannot do with paper and pencil, *except* that the machine does these things faster and more reliably than we can ever hope to do—faster and more reliably by factors of thousands.

The consequences of this large factor in speed and accuracy make a large difference. As an illustration, consider the invention of printing. Before printing was invented, there were books, and scribes could make copies, more or less accurately. All that the invention of printing did was to make it possible to make many accurate copies with a reasonable expenditure of human effort. The consequences, and our dependence on them, are well known and need not be described here. I will not say that the analogy should be pushed so far as

to conclude that computers will produce a similar change in our society, nor will I say that they will not—it is too early to decide that question.

The point that I am making is that you should not expect a digital computer to do anything that you do not know how to do, in principle, but you can reasonably expect that its advantage in speed and accuracy will make great changes in the things we have done with paper and pencil in the past. As a result of these advantages, we now compute many things that we did not compute in the past because they were not worth the human labor and time involved. For example, at the Bell Telephone Laboratories we do problems that cover the breadth of the physical sciences and a little bit of the biological sciences, and we are just beginning what I hope will be a fruitful association with a group of social scientists. In size, the problems run from those that take a few minutes of computer time up to those that take hundreds of hours, with the median around 2½ hours. The median represents about 200,000 elementary arithmetic operations, like adding, subtracting, multiplying, and dividing. Such problems are not generally done by hand calculation; hence, most of what we are now doing we would not do if machines were not available. Much of the computing is an integral part of various laboratory activities and appears to be essential to our present way of operating.

Language of Communications

The use of the word *controlling* in the title of this article does not refer to possible federal legislation but, rather, to how you, as an individual, can "control" a computer to aid in your research. This does not mean how to formulate your work or even what formulas to use but, rather, how to get the computer to do what you want done—how to control this new tool and make it your servant.

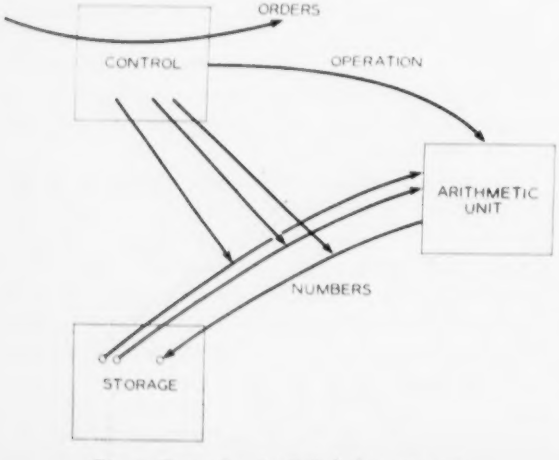

Fig. 1. Control unit of digital computer.

In order to control a computer, it is necessary to communicate with it in some mutually understood language, and the idea of "language" is fundamental to this article. The language is needed, loosely speaking, to tell the machine which, of all the possible problems it might do, is the one you wish it to do next. With a special-purpose computer, where the range of possible problems is small, the language is usually simple, and the description of the particular problem is short. On the other hand, with a general-purpose computer, the possible range of problems is enormous, and it is necessary to provide both a more elaborate language and a more extensive description of the particular problem.

It should be evident that a choice can be made between providing a more extensive language, so that the particular problem may be described in a few words, and providing a simple language and making the description long. Now, the words of the vocabulary of the machine correspond to actual "hardware"—that is, tubes, wires, diodes, and so forth—so that there is pressure on the designer to provide the simplest possible language.

Opposed to the designer is the user, who has to write out the description of each particular problem; he wants an extensive vocabulary so that his writing may be shortened. This is no small matter, although it must be admitted that the early designers and theoreticians seem never to have grasped the magnitude of the difficulties involved. Indeed, it is probably impossible to explain to anyone who has not been faced with coding many problems how difficult it is for a human being to write out, in the typical machine language, what he wants the machine to do. Rarely does even the experienced coder get his program of instructions to the machine correct the first time. Often the trouble shooting takes more machine time than does the actual running of the problem. And it takes a great deal of human time, too.

Elementary Coding Theory

The elements of coding are numbers, addresses, and orders. *Numbers* are what the machines were designed to handle. They may simply be representations of numbers as one usually writes them, although more often, these days, the machines use the base 2 number system rather than the base 10. Some machines also handle numbers together with suitable powers of 10, as is customary in scientific calculations where the range of a quantity may be very large.

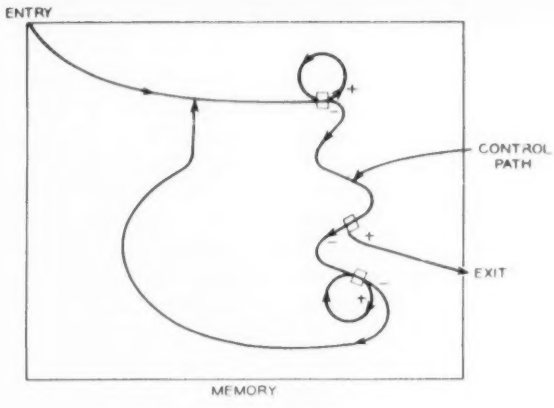

Fig. 2. Storage unit of digital computer.

Numbers are stored in a computer at various locations, which are given *addresses*, to distinguish one place from another. Typically, there is a large section of the computer devoted to storing numbers and orders; this section is often called, anthropomorphically, the "memory". There are, as well, a number of other isolated storage places, such as the "multiplier," the "accumulator," and "buffer storage." The address is used to identify the number that is stored in its location. During the solving of a problem, various numbers may use the same address, each one displacing the previous number; hence, the same address may refer to different numbers during the course of a calculation. This is, obviously, a fruitful source of confusion.

Orders cause various parts of a computer to be interconnected. This allows a number to be transferred from one place, say from a certain address, like 1037, to another, perhaps the accumulator. Orders also activate the various operating processes, such as addition of two numbers and reading in a number from a storage tape.

Typical orders in a machine language handle the transfer of a number, or order, from one location in the machine to another; the various arithmetic operations, such as addition and subtraction; the shifting of a number to the left or to the right in the accumulator; the input and output of numbers and orders; the decision order, or choice of alternative computing routines in accordance with some result that has just been computed; and the logical control of the problem (which I will discuss later).

As an example of a simple addition, we might have the following orders. (i) *Reset* the accumulator to zero *and add* the contents of location 411. (ii) *Add* the contents of location 619 to the accumulator. (iii) *Shift* the sum one place to the right (to cover the case where the sum might have an extra digit on the left) and *round off* the sum by adding a 5 in the extreme righthand column. (iv) *Store* the result back in location 619. It has been said that communicating with a machine in such a language is like talking in microsyllables.

It is often claimed that the only way to understand a computer is to look at things from its point of view. Therefore, let us first look at the computer from the point of view of the control unit (Fig. 1). The control unit connects the various parts of the machine and activates the various processes. A steady stream of orders goes through it, and the machine obeys them in sequence. Decision orders merely decide where the next order is to be found.

It should be carefully noted that the control unit may cause orders as well as numbers to be transferred to the arithmetic unit of the computer. As a result, the machine may alter its own instructions.

Next, let us look at the computer from the viewpoint of the storage unit (Fig. 2). In this view, the control of the problem follows a path described by the location of the order that is being obeyed by the computer. This path (trajectory or orbit) may be pictured as wandering through the storage, with loops and branches here and there. When the control goes around a loop a second time, it may or may not find the same orders that were there before, depending on what the orders in the loop itself have done to the contents of the storage registers since the control was last there.

When preparing a problem in machine language, the human coder usually draws a sketch, or *flow diagram*, of the problem, which is merely a suitable abstraction and modification of the flow of the control through the storage unit (Fig. 3). At each branch point, the nature of the choice of which branch to take is usually indicated (Fig. 3 merely shows plus and minus signs).

Iterative loops (Fig. 4) are the essence of coding. If each order that is written out were obeyed

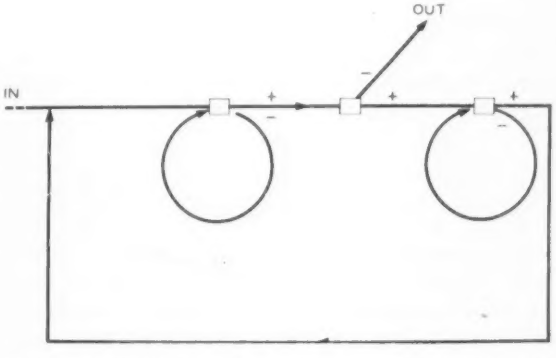

Fig. 3. Abstraction of flow of the control through the storage unit.

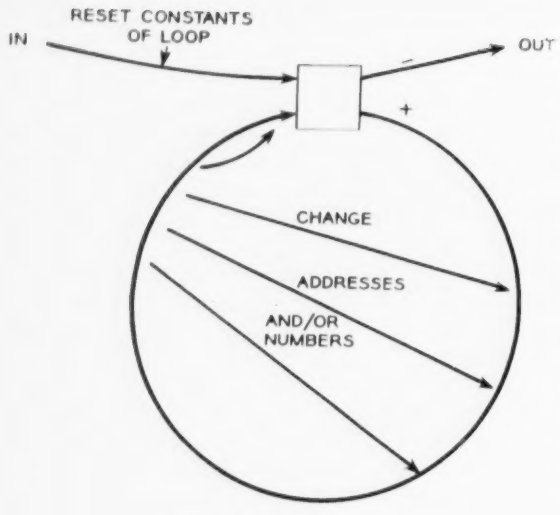

Fig. 4. Iterative loops.

only once, it would be much easier to solve the problem with paper and pencil than to tell the machine what to do. Because you can tell the machine what to do once and then, in effect, tell it to repeat the loop a certain number of times and make certain other changes, such as in the addresses of the numbers used—because of this, machines are worth while. It is evident that loops require a transfer of the control back to the beginning of the loop and that this is conditional on something that is changing; otherwise the loop would go on forever. Special devices are now being built into the machines that will help them to repeat a loop a given number of times before going on to the next part of the program of orders.

In order to see how a computer does a problem, let us consider the *very* simple example of computing

$$y = \frac{x}{1 + x^2}$$

for x running from 0 to 10 by steps of ½ in x. A sketch of a flow diagram is shown in Fig. 5. In the detailed coding, many of the lines in Fig. 5 would become several orders.

One of the first things to be thought of, to ease the burden of communicating with a machine in microsyllables, was the use of subroutines. One soon gets tired of writing out a description of, say, taking the square root of a number every time this occurs in a different place in the problem, or even in different problems. The obvious procedure is to write it out once and then, every time you need a square root, to use this same routine. It is evident that the subroutine for the square root must get information about where the number is and where to return the control when the routine is completed, as well as about what to do with the answer. In simple subroutines, it is customary to put the number and the answer in the accumulator. In general, however, three things must be done in order to use a subroutine (Fig. 6): (i) the numbers that are being used or, equivalently, their addresses, must be stored in some standard location for the subroutine to find, and the addresses where the answers are to go must be similarly stored; (ii) the location to which the control is to go when the subroutine is completed must also be stored somewhere; and (iii) the control of the problem must be transferred to the subroutine when everything is ready. In this way, not only can the same square root routine be used in many different problems, but it may also be used in different places in the same problem.

The next step is the introduction of a library of subroutines—routines, say, for sine, cosine, arc tangent, exponential, logarithm, square root, and sum of products of numbers. Unfortunately, this good idea, when carried very far, raises some new questions. Originally, each subroutine in the library is coded to occupy a certain part of the storage. As

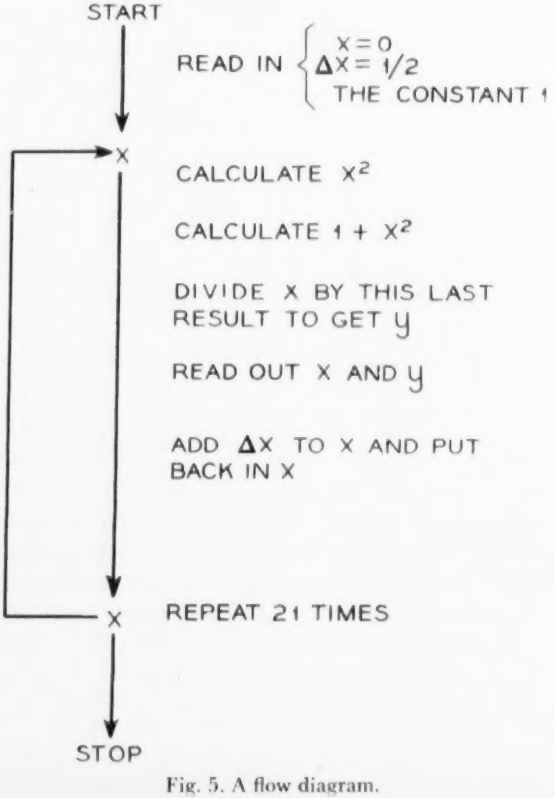

Fig. 5. A flow diagram.

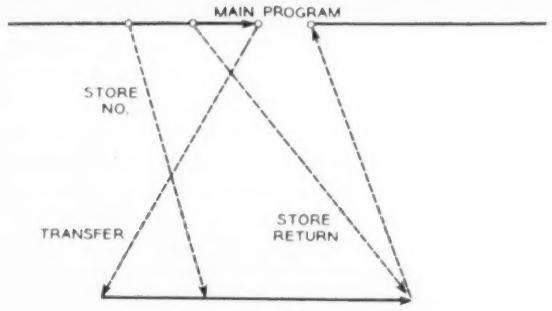

Fig. 6. Use of a subroutine.

the library grows, there is less and less room in which to store all the subroutines without having two of them use the same location in storage, and sooner or later a problem will come along that requires two overlapping routines.

One solution to this dilemma is *regional coding*, which allows the machine to relocate a library subroutine wherever one wants it. In this system, all subroutines are coded as if they started at location 0000, and the machine relocates them so that they occupy suitable places in storage. In order to do this trick, the machine must be able to find out (i) which addresses in the subroutine refer to locations within itself and, consequently, require changing (since the subroutine is now being stored in locations for which it was not coded); (ii) which addresses refer to locations outside the subroutine and hence should be left alone; and (iii) which items (that may look like orders) are numbers and should be left alone. This method may be applied not only to library subroutines but to whole programs. In such a system, the coding is done in blocks, or regions, and the machine puts the pieces together when the program and numbers go into storage at the beginning of the problem.

Advanced Coding Theory

The systematic use of an extensive and elaborate library gradually changes the language of communication used by the coder, since, most of the time, he is writing down the labels of the subroutines of the library. These labels may be called "pseudo orders," and, in effect, form a synthetic language. This synthetic language has a great advantage over the original language of the machine because it is more compressed—that is, a few pseudo orders usually call forth a long sequence of machine orders of some subroutine.

The disadvantage of this procedure is that there is still a lot of storing of numbers and the return of the control before transfer is made to the subroutine. To overcome this defect, interpretive languages which do this storing automatically were invented.

An interpretive language is a new language of communication which is designed by the user to make it easier for him to control the computer. The user writes out the program that describes his particular problem in this synthetic language, and this program is put into the machine, together with a standard description of the process that is necessary to translate from this language into the original machine language.

This process of translating (Fig. 7) picks up the synthetic, or pseudo, orders, one at a time, and isolates and stores the particular synthetic operation in the order as well as the addresses of the numbers that are mentioned in the order. Generally, a constant is next added to the digits which specify the operation, and the control of the machine is transferred to this location. Since each operation has a different label, the location transferred to is also different. Each of the locations that corresponds to a synthetic operation is the beginning of a subroutine that describes, in machine language, the particular process. Thus, this library of subroutines is, in effect, a dictionary of translation between the two languages.

In most of the synthetic languages that have been made so far, the process, as sketched, is simple when compared to that of translating from Russian or German into English. One reason for this is the fact that the inventor of the synthetic language has to mechanize the process himself and naturally excludes all "irregular verbs" and such difficulties. Another reason is the fact that we simply do not know enough about the advantages of many of our linguistic peculiarities to be able to make good use of them.

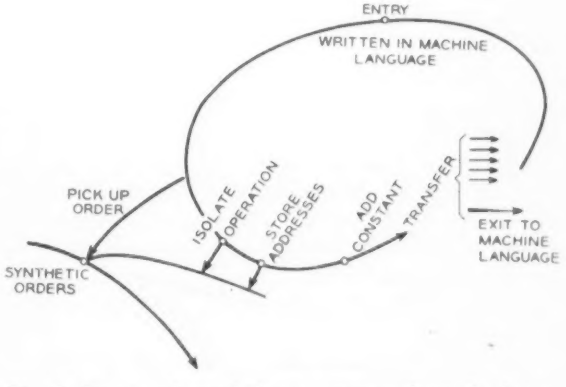

Fig. 7. Process of translating a program from the interpretive language into the original machine language.

Although the loop (Fig. 7) which the machine goes around in translating each synthetic order is written in the machine language, the user sees only the pseudo language—a language that was created to be simpler, from his standpoint, than the original machine language. The pseudo language is generally richer in vocabulary and is highly compressed in comparison with the machine language. Thus, the coding of a problem in the pseudo language is much shorter, generally seems more natural to the user, and is much less likely to contain errors.

It may be said that the introduction of pseudo languages was the first major step in the harnessing of the digital computers to fit them for human use. Communicating with a computer *in* its own microsyllabic language is very difficult for human beings; with interpretive languages, it is much easier.

The chief difficulty in interpreting a synthetic language is the fact that every time you come to the same synthetic order, the translation takes machine time. To avoid this waste, the translation may be written out by the machine once—technically, this is called "compiling"—and then the written-out program is used by the machine.

The chief difficulty in compiling is that, when trouble occurs, one is left with a program that is not in the synthetic language, and the trouble shooter must dig into all the details and difficulties of the compiled program. Thus, the user needs to know both languages, and much of the advantage of the synthetic language vanishes. There are ways around this difficulty which help, but it remains a nuisance, nevertheless.

It is customary, in machine language, to assign the addresses where the orders and numbers are stored. The difficulty here lies in the fact that these addresses are fundamentally "nonsense syllables" and that human beings are ill equipped to deal with them. So long as nonsense syllables are used, you can expect that the language will be difficult for human beings to handle, and that there will be many mistakes.

One of the first steps that was taken to escape the use of nonsense syllable addresses was to introduce "symbolic addresses" that have some mnemonic value, such as putting the quantity x in address x. The machine assigns definite machine addresses to each symbolic address and keeps track of the translation, so that all references are consistent. This system blends in well with the methods of regional coding that were mentioned earlier in this article.

Another, somewhat later, plan was a "nonaddressed order system," in which the orders were not given any addresses and any modification of orders was made by modifiers that immediately preceded the order. In terms of language, modification of meaning was accomplished by the introduction of prefixes.

There are, at present, a number of vigorous efforts being made to produce the direct "algebraic coding" of the algebraic equations themselves. Perhaps the most widely publicized of these is one called "Fortran" (meaning "formula translation"), which is just becoming available. Although there has not been time to try out this system under extensive use, it promises to make the coding of a large class of problems relatively easy. It is to be expected, however, that there will be other efforts in this direction.

Let me pause and recapitulate. From programming the first large-scale digital computers in their microsyllabic languages, with continual references to nonsense syllable addresses, we have moved, step by step, toward the use of languages that are more suitable for human beings to use. First, we introduced subroutines, and then libraries of subroutines, to gain compression. Next, we introduced regional coding, to allow the machine itself to rearrange the separate parts of a program. This was followed by symbolic addresses, to get some mnemonic value in place of the nonsense syllable addresses, and, still later, by a nonaddressed system, with prefixes to modify the words. Finally, we have algebraic coding, which is an approach to the writing out of the mathematical equations themselves as the input to the machine.

The Future

With all this progress in harnessing the digital computer, are we now done? The answer is a definite "No." The search for languages of communication between human beings and the computers has just begun.

The foregoing description of the progress in the study of languages of communication may be said to have been mainly concerned with that part of mathematics that is usually called "analysis." Languages that deal with statistics are not so highly developed. Those that deal with business applications, although they have been studied for a long time, appear to be still in their infancy. In the field of combinatorial mathematics, it is not clear what the basic operations are, let alone what would constitute a suitable language.

Another area for research is centered around the idea of "redundancy." The English language is about 60 percent redundant in the sense that one can delete about 60 percent of the usual message and still make sense out of the rest. Since human

beings and their languages have evolved together, it is reasonable to assume that this redundancy is, in some way, related to the human nervous system. Less redundancy would increase the probability of misunderstanding, which is all too common anyway, while more redundancy would slow down the rate of communication.

It is important to note that much of this redundancy is useful in the sense that human beings can use it to catch mistakes in a message. All of the synthetic languages that I know about were deliberately designed to have as little redundancy as possible, and what redundancy is left, generally speaking, is not useful. It is immediately evident that these synthetic languages are still not well suited for human use. Yet the problem of designing a synthetic language for use in communicating with a machine in such a way that the redundancy is useful is far from being solved. We do not seem to know how to do it. Of course, one can write out a program twice and thus get a 50 percent redundancy, but, by and large, this is not a *useful* redundancy. As a guess, it would seem that the usefulness of redundancy is bound up, in part, with the density of synonyms and antonyms in a language and, in part, with grammatical structure. But I, at least, do not know how to devise a suitable synthetic language for use with computers.

Another difficulty is the fact that our language frequently does not have a unique meaning. Why this is so is left for you to conjecture, but it is certainly true. We depend on context a great deal, both in speaking and in writing.

Another avenue of research is that of giving many of our current words and phrases (such as *simultaneous equations, integrate,* and *solve a differential equation*) better meanings. Our present methods of handling words of this kind leave a lot to be desired. This avenue of research lies mainly in the field of mathematics.

Still another avenue of research is the algebrization of computers, by which I mean enabling them not only to recognize algebraic symbols and translate these into numerical operations but to handle directly the expressions themselves. So far, it has been demonstrated that we can handle (i) differentiation of analytic expressions of elementary functions and (ii) power series (truncated to a fixed number of terms).

One can see how to go about constructing (i) an algebraic checking routine, and (ii) a routine for comparing expressions with those in a standard table.

It is not clear how to program routines for (i) integration by parts, (ii) factoring and arranging elaborate expressions, or (iii) determining good bounds by means of inequalities.

I hope this shows that we have not reached the end of our search for languages for communicating with computers but have only begun. The search is fascinating because, among other things, as we find out about languages, we find out about ourselves; we created the languages and, in some sense, the languages are suited to our own nervous system, since we evolved with them.

This designing of languages to enable human beings to communicate with large-scale digital computers should provide a fruitful approach to many new problems in linguistics. The problem is both restricted enough and flexible enough to provide a good experimental tool in approaching many language problems.

Note

1. I am mainly interested in the use rather than the design of computers, particularly in the scientific, as contrasted with the business, applications.

Ovigenic-Ovisorptive Cycle in the Economy of the Honey Bee

STANLEY E. FLANDERS

Dr. Flanders is professor of biological control and entomologist in the Experiment Station of the University of California at Riverside. His interest in the economy of the honey bee stems from 30 years' experience in studying, under controlled conditions, the life-histories and economies of approximately 100 species of parasitic Hymenoptera, representing ten families.

THE honey bee is too often considered in isolation, as if it were an exceptional insect." The validity of this statement, as pointed out by Ribbands (*1*), rests on the fact that the honey bee is a typical member of the Hymenoptera, that group of more than 60,000 species whose attributes have on various occasions provided the basis for social organization.

Two of these attributes, known in the honey bee as well as in certain genera of parasitic Hymenoptera (*2, 3*), are the external inducement of ovulation and the correlated phenomenon of ovisorption. The possession of these particular attributes enables a species to maintain itself by the reproduction of a relatively few females. The ovary in such species apparently functions not merely for reproduction per se but, through its ovigenic-ovisorptive cycle, to conserve reproductive material, prolong the life of the female when oviposition sites are scarce, insure the full utilization of oviposition sites as they become available, and initiate reproductive diapause so that the chance of survival of the species under conditions unfavorable for reproduction is enhanced (*4–6*).

Since these attributes—externally induced ovulation and ovisorption—are known to play a highly important role in the economy of the parasitic Hymenoptera, their consideration as primary bases of social organization in the ants, bees, and wasps is inevitable. It is in the populations of social species that the proportion of female reproductives, or "queens," attains its minimum.

In hymenopterous females in which ovigenesis continues after oviposition begins and in which each egg is deposited immediately after it passes out of its ovariole, as in the queen of the honey bee, the egg is absorbed if it is not deposited soon after its growth is completed (*5*). Ovisorption in the newly gravid female may be initiated by the presence in the ovary of a specific number of mature eggs.

At a constant temperature of 80°F, the genesis of the ovarian egg requires 3 days; its degeneration, a few hours. This degeneration occurs within the ovariole, not in the oviduct, and is obviously an effect of the egg-follicle's reversing its constructive function to that of extracting the egg content and dissolving the egg chorion (*7*).

The extent to which the egg is absorbed varies with the species; the ovarian eggs of pteromalids disappear completely, those of certain encyrtids have only the egg content extracted. With *Encyrtus fuliginosus* Comp., for example, the collapsed shells of the absorbed eggs accumulate in the body cavity, having apparently been forced by the pressure of the ovigenesis through the ovarial sheath. This penetration of the sheath can occur readily because the aeroscopic plate of the egg, when the shell is collapsed, forms a sharp, spinelike process. *Encyrtus fuliginosus* is an exceptional species in that the inhibition of oviposition shortens the life of the female, an effect, apparently, of the accumulated egg shells' blocking the circulation of the blood (*2*).

In most Hymenoptera of this type the inhibition of oviposition lengthens the life of the female, and the egg remnants, if any, remain in the ovarioles without affecting either ovigenesis or ovulation. In any such female the proportion of eggs completely absorbed depends on the proportion ovulated and deposited. This is the case in the honey bee (*8*).

Ovigenesis in the gravid queen is continuous, but oviposition is not. The shell of the unovulated egg, as well as its content, is absorbed into the blood stream. Many of the eggs, not completely absorbed, appear as flat, yellow disks (*3*). An accumulation of these disks in the ovarioles results in the "yellow ring" that is often observed around the base of the ovary in old queens. It is quite possible that the queen, when depositing eggs at the rate of 1500 per day, is absorbing, each day, an additional 1500 eggs, so that her actual daily production of eggs is 3000. At all moments during brood production, each of the queen's numerous (±350) ovarioles may contain from two to six ripe, follicle-enclosed eggs.

It seems probable that, with species in which the occurrence of ovulation is dependent on external

stimuli, the possession of numerous ovarioles will result in the prolonged retention of the mature ovarian egg and consequently in the subjection of each egg to the ovisorptive process. Such an inherent delay in ovulation would result in all deposited eggs' having a reduced amount of yolk. If the amount of such reduction is excessive, the deposited eggs will not develop. The nonviable eggs that are occasionally seen in the bee colony may be thus derived.

The classic studies of Bier (*9*) on caste determination in the ant *Formica rufa* indicate that the worker is derived only from ovarian eggs which have a reduced amount of yolk. He observed, however, that the predisposition to become a worker may be nutritionally counteracted during the early stages of larval development.

The limitation of worker development to eggs that have a reduced amount of yolk is considered to be characteristic of the social Hymenoptera. In highly organized hymenopteran societies, such as those of the honey bee and army ant, in which colony reproduction is limited to fission or swarming and in which differential feeding of the larvae is segregated either in time or in space, the queen appears to have lost the capacity to deposit yolk-replete eggs—that is, eggs which develop into reproductive females regardless of the nutrition of the larvae. All of the fertilized eggs deposited by such a queen would be predisposed, by the reduced amount of yolk, to become workers. The larvae from such eggs, however, may become queens if they receive materials that inhibit development into workers and stimulate development into queens. It is evident, therefore, that the prevailing assumption that the worker caste in the honey bee is initiated during the larval stage may be unwarranted.

Queen production necessitates the counteraction of the predisposition of an egg to become a worker. According to Snodgrass (*10*), a larval diet containing specifically inhibitory ingredients suppresses the development of worker characters. The large size of the queen cell directly or indirectly inhibits the development of a worker therein.

It is significant that in the leaf-nesting ant *Oecophylla longinoda*, all of the fertilized eggs that are deposited by the queen become workers (*11*). Since the queen in this species is the progeny of the unmated worker, segregated feeding of the larval progeny of the queen is unnecessary. In certain ants some of the eggs produced by the worker may be yolk-replete and consequently larger than any of those produced by the queen (*12*). This is probably correlated with the relatively few ovarioles possessed by the worker.

In all of the social Hymenoptera, queen production is facultative (*6*). The queen in the more primitive social species may be derived either from a fertilized, yolk-replete egg or from an adult worker in which reproductive diapause is nutritionally counteracted.

The queen in highly organized species characterized by segregated feeding of the larvae may be derived from a larva which is predisposed to become a worker, provided that the larva is properly fed. Workers and queens may also be derived from unfertilized eggs (*13*) deposited either by a queen or by a worker, as was demonstrated by Mackensen (*14*).

We can logically conclude that the ovigenic-ovisorptive cycle which characterizes the social Hymenoptera plays, in the honey bee, a basic role in the economy of the species, first by allowing greater flexibility in oviposition, so that the queen can take full advantage of the number of brood cells as they become available, and second, by predisposing all of the eggs deposited by the queen to become workers, so that the ratio of queens to workers can be subsequently determined by the nutrition of the larvae and a more exact environmental control of caste production can be attained.

The social organization of the ants, bees, and wasps, as observed since the time of Jean Henri Fabre, demonstrates in the adult female an evolutionary sequence of three phenomena—reproductive diapause, division of labor, and morphological differentiation. It seems probable that these phenomena are initiated in the maturated ovarian egg and that their realization is governed by subsequent circumstances. The physiological and anatomical differences that characterize the adult worker and the queen of the honey bee may be determined by differences in the amount or quality of ovarian hormones produced during larval and prepupal development, as Haydak (*15*) has postulated.

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Karst Landscapes of Cuba, Puerto Rico, and Jamaica

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HUMID regions with areas of soluble or partially soluble rock, commonly limestone, frequently develop karst topography. The normal karst erosion cycle is characterized by distinctive physiographic features in each stage of the cycle. In youth, drainage is generally by surface means, with only a small percentage of the potential runoff percolating through the soluble surface rock. This minute amount of subterranean water excavates a few small caverns and produces a paucity of small surface sinks (dolines). Thus the surface topography is frequently characterized by generally flat-to-rolling land, a few solution basins, and narrow V-shaped stream courses.

As youth gradually gives way to maturity, the drainage is predominantly underground, multitudinous caverns and galleries are formed, and the surface of the land is pocked with numerous dolines, ponors (small, steep-sided, flat-floored sinks), and uvalas (large, steep-sided, elongate sinks). The surface landscape is characterized by undulating-to-rolling topography with few or no surface streams, closely spaced sinks, and frequent yawning caverns. As old age approaches, the drainage is again on the surface, at a lower level, since solution has removed most of the original rock veneer. Impermeable rocks outcrop in places, and residual remnants of limestone occur, known regionally as "haystacks," "hums," or "mogotes." Usually these remnants are honeycombed with solution channels and caverns (*1*).

Karst areas in various stages of the erosion cycle are to be observed in a number of Caribbean islands. Karst regions of the Caribbean have developed on uplifted Cretaceous and Tertiary limestones, and striking similarities and differences of major karst regions are readily observable. Three karst regions of considerable areal extent with similar and contrasting landscape features are western Cuba, north-central Jamaica, and northwestern Puerto Rico (Fig. 1).

The purpose of this article is to describe and differentiate landscape features in each of these karst areas. In order to accomplish this objective, it is necessary to delineate, rather specifically, each major karst area, comment on physical features within each, describe human use patterns, and correlate or contrast conditions which are like or unlike in the three regions. Each karst area will be discussed separately, and obvious comparisons and contrasts among them will be expounded.

Cuba

Near the western limits of the island of Cuba is the rough and rugged karst hill-land known locally as the "Guaniguánicos." The Guaniguánicos are part of the Cordillera de los Organos, situated in the northern portion of the province of Pinar del Rio. This karst area, lying roughly between 20°10′N and 22°45′N and 83°30′W and 84°05′W, is composed of Cretaceous limestones that have been uplifted and severely tilted (*2*) (Fig. 2). The area is characterized by rugged, tall, isolated, steep-sided mogotes interspersed with deep, sharply outlined, flat-bottomed valleys, or uvalas. Local relief, although not great when compared with mountain systems, is considerable, varying from 500 feet to almost 1500 feet.

The mogotes are honeycombed with solution channels, galleries, and caverns and are generally flat-topped and steep-sided. These mogotes range in size from small hills to large mesalike formations several square miles in extent. Meyerhoff suggests that increased elevation results in a diminution of the number of mogotes per unit area (*3*, p. 288). He has shown, for example, that in Puerto Rico in areas where local relief approximates 350 feet

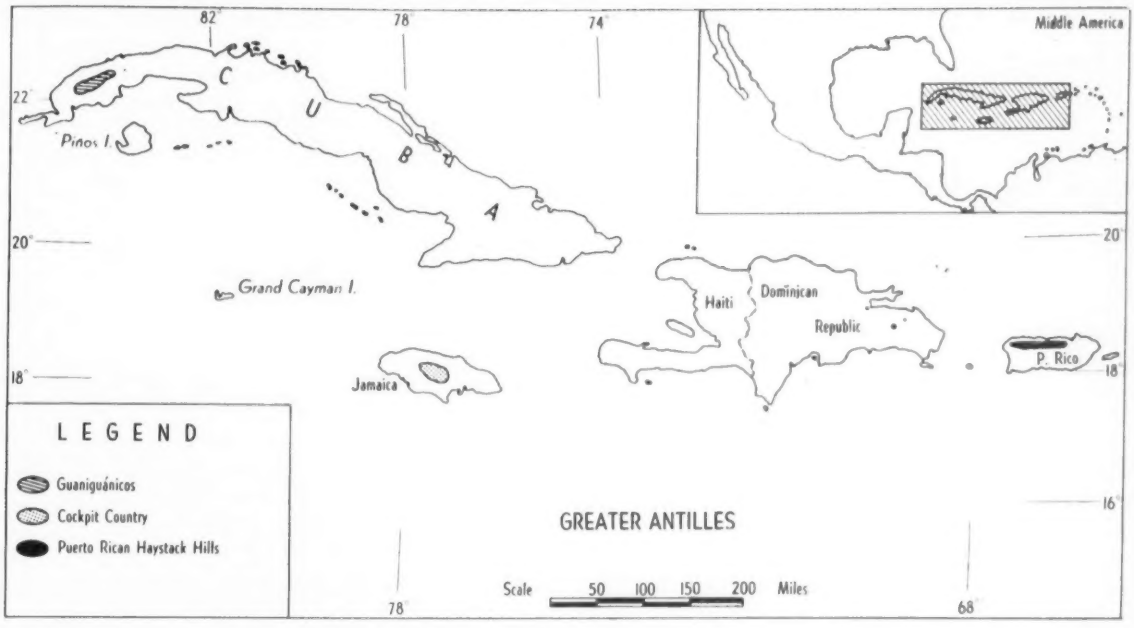

Fig. 1. Generalized map showing location of Cuban, Puerto Rican, and Jamaican karst regions.

mogotes number about nine per square kilometer and depressions are about 0.3 kilometer apart. In other areas of Puerto Rico where the local relief is about 700 feet, only four mogotes are present per square kilometer, and valleys are 0.5 to 0.6 kilometer apart. In the Sierra de los Organos, where local relief is 1400 to 1500 feet, depressions 1 to 1.2 kilometer apart enclose a single massive mogote in 1 square kilometer (*3*, p. 288).

Most valleys exhibit a close correlation to underlying rock structure. Larger valleys are oriented parallel to the southeast-northwest strike of the beds, but several transverse valleys are observable, which are apparently not structurally controlled. Valleys vary in size from a few acres to several square miles (*3*, p. 282).

Drainage, as would be expected, is both surface and subterranean. Some subterranean water finds an outlet in surface streams. Surface drainage is predominantly to the southeast; the major watercourses are the Rio Cuyaguateje, the Rio Hondo, and others.

Another salient aspect of the physical environment is climate. Climatic conditions in karst regions of Cuba, Puerto Rico, and Jamaica are similar in many respects, but certain significant differences are observable. In the Guaniguánicos, precipitation varies from about 50 inches to more than 70 inches a year. June, July, September, and October are the driest months. Average warm-month temperatures approximate 80°F, while 70°F is the approximate average for the cold month. Maximum temperatures approach 100°F, while minimums occasionally drop into the 40°'s. Cuba experiences greater temperature extremes than do Puerto Rico or Jamaica, because of its greater size and proximal location to North America. The Guaniguánicos, lying in the western Caribbean storm track, experience severe rain- and windstorms, accompanying hurricanes. This western section of Cuba has been struck by almost 40 percent of all Cuban hurricanes (*4*, p. 92).

Extant natural vegetation reflects adjustment to climate and edaphic conditions. Original natural vegetation was largely tropical in nature. Some species are evergreen, while others are semideciduous, losing their leaves during the dry season. Remnants of the original vegetative cover are found predominantly in the lowlands and at the base of the mogotes. Ceibas (*Bombax ceiba*) grow abundantly in many cracks and crevices of the soluble limestone as well as on the various ledges of rock. Near the base of the mogotes scattered royal palms (*Roystonea regia*) are found. Slopes of the mogotes are so steep as to preclude vegetative growth except on ledges or in cracks. The tops of the hills are often covered with brush vegetation, and these brush-covered mogotes appear from a distance not greatly unlike giant green sponges. Some common species of this area include *el ceibon o drago* (*Bombax emarginatum*), *la palma de sierra* (*Gaussia princeps*), and *el roble caiman* (*Ekmanianthe ac-*

tinophylla) (*4*, p. 113). The lowlands have been cleared for cultivation and are essentially void of natural vegetation.

Soils of the Guaniguánicos closely reflect symbiotic relationships to vegetation and exhibit marked influences of climate and parent material. Valley bottoms have a thick soil mantle, frequently clayey in texture. In general, the mogotes have a scarcity of soil cover, and those soils that are present are high in mineral content and low in organic matter. Drainage on the mogotes is good to excessive, thus accounting, in part, for scrub vegetation on hills. Matanzas soils are found in the valleys (*4*, p. 107). These soils are permeable and rapidly leached, indicating soil cover in depth. The top soils are characterized by their brownish-red color, friable texture, and depth. Below this topsoil the color changes to a darker red, and the soil is slightly plastic but still permeable. This soil is acidic, with a *p*H of 6.2 to 6.8 in all horizons (*5*).

Throughout the karst area of Cuba population is sparse, with the larger clusters of people being found in the more fertile valley bottoms. This population concentration in the valley bottoms reflects the paucity of level land and the agricultural inclination of the local inhabitants. Generally, the agricultural region consists of moderate-sized, semi-isolated farmsteads, rather than the large plantation holdings such as those which are located in the more level and productive regions of Cuba. Principal commercial crops include sugar cane and tobacco, and major subsistence crops are corn, rice, and beans. Grazing is a localized activity subsidiary to farming. The mogotes are useful only as tourist attractions or for brush, which is used in charcoal manufacturing.

Urban centers in the Guaniguánicos region of Cuba are generally lacking, the largest cluster of population (Viñales) being slightly under 2250 in size. Rural population predominates, with a minimum number of villages furnishing the service needs of the rural inhabitants. Rough land and minimal economic opportunities afford scant possibility for great population expansion. The general scarcity of population and the absence of large urban centers are reflected in the meagerly developed road network. Hard-surfaced highways are generally absent in the area, and only a skeletal network of other roads exists. Only one hard-surfaced road completely traverses the region from Pinar del Rio, through Viñales, toward La Palma (Fig. 3). The majority of the roads in this portion of Cuba skirt the southern extremity of the region. No rail lines cross the region, and the nearest railhead is at Pinar del Rio, south of the mountains.

Puerto Rico

Conspicuous karst features of Puerto Rico are located on the north coast between Bayamon and Aguadilla. Specifically, this karst region lies between approximately 18°19′N and 18°27′N and 66°10′W to 67°07′W, in its maximum limits. Locally, the limestone belt may be substantially narrower and in places temporarily discontinuous. Uplifted marine limestones are almost horizontal, with a dip of 1 to 6 degrees northward toward the Atlantic coast (*3*, p. 265). Small, conical mogotes

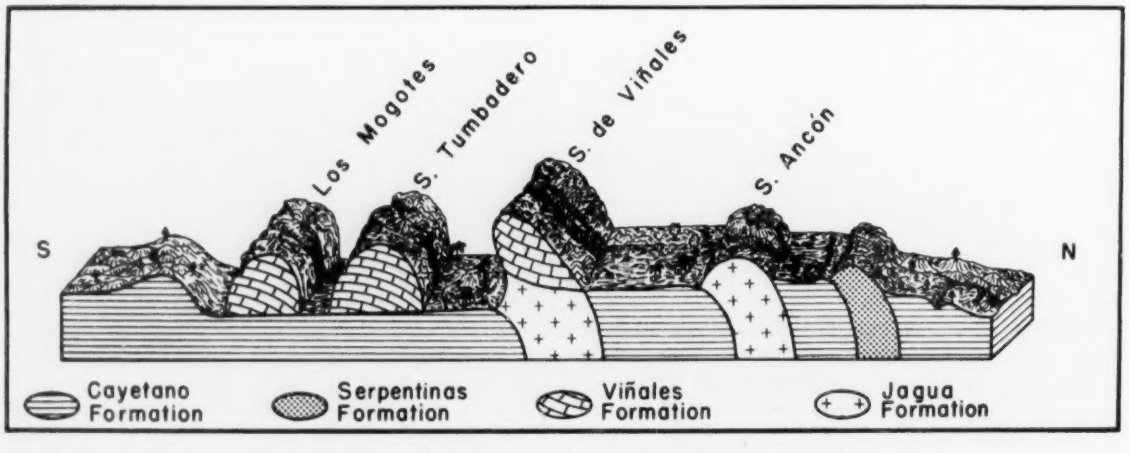

Fig. 2. Structural diagram of the Cordillera de los Organos. Approximate location of this cross section is shown in Fig. 3. Cayetano, Serpentinas, and Viñales formations are Cretaceous members, and the Jagua formation is of Jurassic age. Each of the most significant ridges is named: Los Mogotes, Sierra Tumbadero, Sierra de Viñales, and Sierra Ancón. [From a diagram in *Geografia de Cuba* (*4*) and a description in *Itineraires Botaniques dans l'Ile de Cuba* (*13*)].

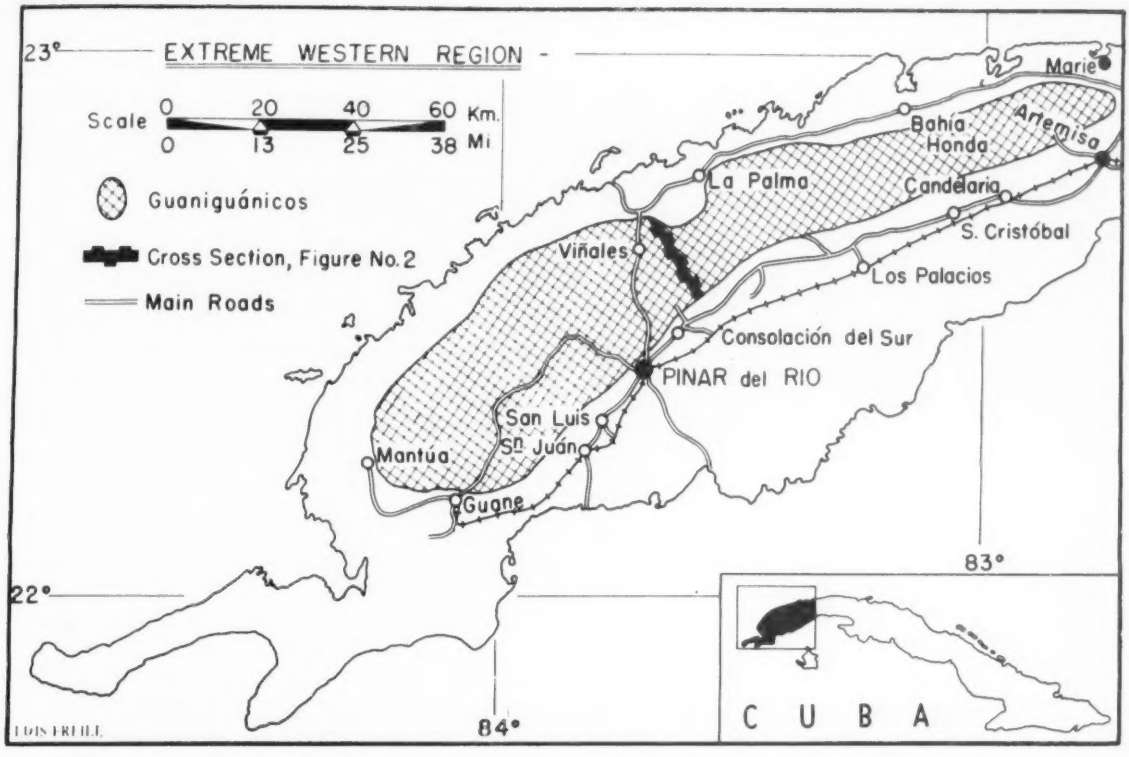

Fig. 3. Generalized diagram of the Guaniguánicos region of western Cuba.

alternate with valley bottoms and sinks. Locally, these mogotes and intervening sinks may be arranged in rows, but often no such orientation is apparent. Local relief is generally less than 400 feet. Pepinos—elongate, knobby, cucumber-shaped hills, trending generally northeast-southwest—are probably forerunners of mogotes. As erosion proceeds the pepinos break up into the typical cone-shaped mogotes characterized by a steep western face. Apparently, the north and east faces are modified by hard, driving rains, which approach from those directions (*6*).

Deep, numerous sinkholes or small solution valleys between the hills are encountered. Narrow, undulating valleys are pocked with sinks, galleries, and caverns. Often sinkholes of up to ¼ mile in diameter are found, with smaller dolines inside them. In many places these dolines are so numerous that only a narrow ridge divides them. Drainage in this area makes its way into the dolines and small valleys. From there it disappears from the surface and travels in long, underground, solution passageways. A few youthful streams have succeeded in cutting deep into the massive limestone, and along these streamways deep, V-shaped, gorge-like valleys traverse the karst lands. The supply of underground water is abundant, but the water table is found at considerable depths, thus discouraging its use. Principal rivers which traverse the karst lands include the Guajataca, Arecibo, Manatí, and the Rio Plata, all flowing from south to north (Fig. 4).

The Puerto Rican karst region is a humid section, with stations such as Bayaney, located in the lowlands, reporting 85.06 inches of precipitation a year. At this station no month, with the exception of January, has precipitation of less than 3.75 inches. Bayamon, another representative station within the karst region of Puerto Rico, has an average annual temperature of 76.6°F and an annual precipitation of 77 inches. No month is dry, but a wet and a less wet period are encountered. May through November are the wettest months. The less wet season of this region is from December through April. Temperatures likewise reflect this two-season arrangement with the months of highest rainfall (May through November) also having the highest temperature recordings. Monthly temperature averages of this hot, wet season range from about 78° to 80°F. Cool-month temperatures vary from about 74° to 76°F.

As in Cuba, the karst topography area of Puerto Rico has native vegetational cover of low shrubby brush and forests. The mogotes, because of their

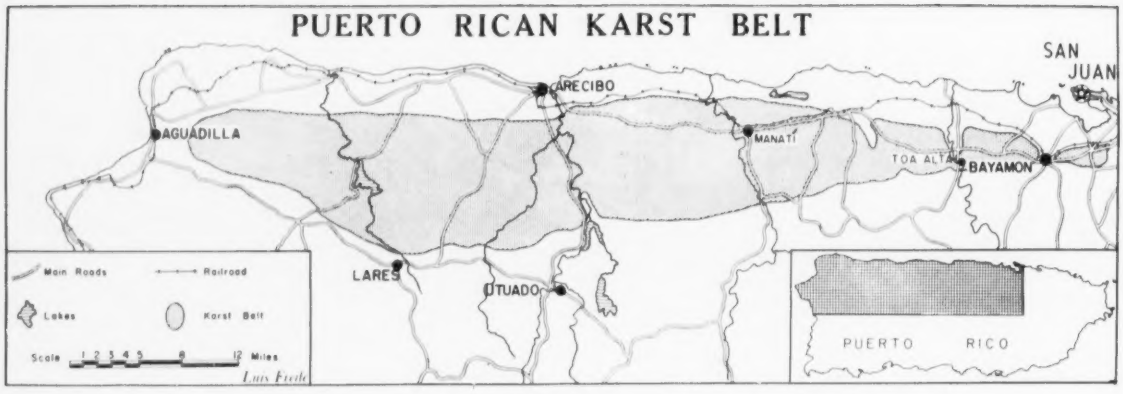

Fig. 4. Puerto Rican haystack hill region. The northward-flowing rivers are, from west to east, Guajataca, Arecibo, Manatí, and Plata.

rapid runoff and the percolation of surface water, support only a sparse, shrubby forest of trees located in the many cracks and crevices of the honeycombed prominences (Fig. 5). These trees are used locally in the making of charcoal and furnish much of the wood used as fuel on the island. In the valleys, somewhat larger and denser growths of brush and forest land were originally present; however, since the introduction of domestic crops, this cover is largely absent. Some common species of this area include *capa blanco* (*Lonchocarpus glaucifolis*), *gauba* (*Inga laurina*), and *capa* (*Lonchocarpus blainii*) and thorny shrubs such as sisal (*Agave sisalina*).

Soils within the karst area of Puerto Rico are probably much better known and studied than are those in any other Caribbean karst region (*7*). They show a close relationship to slope, drainage, and parent material. On the uplands, the soils are generally thin, sparse, stony clays and are excessively drained. On the other hand, soils of the valleys are deep, heavy textured, high in organic matter and plant nutrients, clayey, and well drained. Upon the residual hills, the principal soil series are the Tanama, Colinas, and the Soller. The hill soils are poor for agricultural purposes because of their shallow profile, low organic content, and high degree of stoniness. These soils are predominantly clay loam to stony clay in texture. The profile consists of a shallow zone of black, granular, calcareous clay loam overlying another zone of friable, gray clay loam and pieces of disintegrated limestone rock. Soils series such as Bayamon, Matanzas, and Espinosa are typical of the lowlands and valleys. These soils are dark colored, deep, high in plant nutrients and organic material, permeable, and rapidly leached. Textures vary from clayey to sandy clay. Bayamon, Matanzas, and Espinosa series are generally characterized by an upper zone of light-brown granular soil 6 to 10 inches in depth. Below this zone is a subsoil layer of yellowish-brown or reddish-yellow fine cloddy clay about 20 to 25 inches in thickness. Situated under the upper subsoil zone is a lower subsoil layer consisting of 15 to 30 inches of reddish-yellow friable clay. The parent rock, limestone, occurs at varying depths, and the whole profile varies from nearly neutral to heavily acid (*8*).

Agricultural endeavors are principally of the nonplantation type. Again, as in Cuba, much of the land remains in brush and forest cover. The great majority of the indigenous population of this region are farmers, with only a few small villages dotting the landscape. The farms are relatively small and semi-isolated, with the family providing for its food and shelter needs. The farmsteads are almost universally located in the valleys and sinks, while mogotes and slope lands remain primarily in forest cover. Principal commercial crops include sugar cane, tobacco if the depth of the soil is greater than 10 inches, with minor amounts of coffee in the more protected areas, pineapple, and grapefruit (Fig. 6). Sugar cane is by far the ranking crop of the area, both in terms of the number of acres planted and harvested and the value of the harvest (*9*). Subsistence crops, which rank next to sugar cane in total acreage, are corn, beans, *frutos menores,* and harvested forage. Animal husbandry is carried on locally, subsidiary to farming practices. Farm incomes are also supplemented by the cutting of wood for fuel and the manufacture of charcoal, both of which are used throughout the island.

Rural population is dominant, and urban centers are few. Largest urban concentrations within and adjacent to the karst area are Aguadilla, Bayamon,

Toa Alta, and Manatí. Population is concentrated in the lowlands and sinks, the mogotes being barren of settlement. The small villages that are present in the region exist solely for the purpose of rendering services to the rural inhabitants. Resettlement schemes of various sorts have increased the population density of the region as a whole. The eastern half of the region is more densely settled than the western half, probably because of the magnetic attraction of San Juan. It must be remembered, however, that precipitation drops off in the western part of the island, and this reduction in moisture may be a factor in lower population densities in the west.

Transportation facilities in the area are inadequate in comparison with most sections of the United States. No railroads traverse the area, but the main insular line flanks the region on the north, and occasional branches penetrate the limestone hills for short distances. The road net is sparse, with major highways generally avoiding the region, much as do the railways. The few good roads that are present are feeders both to the principal highways of the island and to the nearby railroads. Black-top roads penetrate the area to connect with highland routes in the insular road network. Unimproved dirt roads are somewhat more numerous, but the local inhabitants usually travel on trails. Transportation routes show an affinity for the more densely settled eastern sections. Some western regions are almost completely lacking in road, rail, or trail facilities.

Jamaica

Within the central, northern, and northwestern portion of the island of Jamaica (*10*) lies an area of karst topography commonly known as the "cockpit country." The name *cockpit* has been applied because the sinkholes resemble the small circular areas on which cockfights are held. The "cockpit country," like most of the island, is underlain by tertiary limestone, white in color, moderately soluble, and only slightly tilted. The greater part of this region lies approximately between latitudes 18°00′ and 18°04′N and longitudes 77°00′ and 77°52′W. Topographically the area is very rough and rugged, with deep sinkholes alternating with tall irregular mogotes (*11*). These mogotes are conical-shaped residual hills similar to those of Cuba and Puerto Rico. Local relief between the summits of the mogotes and the base of the sinkholes is as much as 500 feet. Throughout this region of karst topography numerous dolines and inverted cone-shaped sinkholes, locally called "arenas," are present and vary greatly in size.

Fig. 5. Shrub-covered mogote hillside in Puerto Rico.

Fig. 6. Cane field in the limestone hill country of Puerto Rico.

In this area, solution results in the formation of a series of circular dolines or arenas, appearing somewhat like inverted cones with extremely irregular sides. The circular form is persistent throughout, and the dolines terminate, in most instances, in a sinkhole at the bottom. These dolines are of all sizes and range in diameter from about 30 feet to more than 175 feet. Often only a small, narrow, winding, frequently interrupted ridge separates these sinks. Many times the ridges which divide the sinkholes have steep or vertical sides of considerable height. The principal trails of the area are located at, or on, the crest of the broader ridges (Fig. 7).

Few surface streams have developed, since the rain water seeps into the ground and percolates down through the limestone by way of fissures, caverns, and galleries. In this manner great vol-

Fig. 7. Aerial view, from altitude of 7000 feet, of a portion of the "cockpit country" of Jamaica, showing brush-covered hills, paucity of watercourses, and general absence of transportation facilities. Note particularly the large, partially cleared sink and the circuitous trail following the ridge line above the sink. [Courtesy Director of Surveys, Kingston, Jamaica]

umes of water flow in underground stream courses and, as a result, form large caves and subterranean water passages. For example, the Cave River, located northwest of the village of Spaldings, flows through 13.5 miles of subsurface channel before coming to the surface. In 1950, after particularly heavy rains, a temporary lake was formed in Cave Valley. Not to be confused with the Cave River valley, the Cave Valley is located roughly 2 miles northwest of Anderson's Town. Not uncommonly sinkholes become temporarily plugged, and lakes may form. Surface drainage is almost completely lacking in the northern half of the "cockpit country." The lack of surface streams stands in mute testimony to the high permeability of the underlying limestone.

Climatically the "cockpit country" of Jamaica receives between 60 and 75 inches of precipitation a year and, like the remainder of the island, receives a double maximum of precipitation in May and October. No season is dry, but February, March, and July are commonly less wet than the other months. Lying near the western Caribbean storm track, this section of the island is likely to receive heavy amounts of moisture during the hurricane season (August to November). Such heavy rainfall results in many sinkholes becoming temporary lakes. The example of the flooded Cave Valley, on 17 October 1950, has been previously cited.

Temperature variations in this karst region are similar to those of the rest of the island. Annual mean temperatures vary between 70° and nearly 80°F in the "cockpit country" (*12*). This variation in annual temperature is primarily a function of exposure and elevation. Temperature range throughout the year is slight, with the months of May through October being the warmest. Annual range of temperature at an adjacent station is only about 5°F.

Jamaican karst vegetation is closely related to the karst regions already discussed. Low scrub brush and forest predominate (Fig. 7). The mogotes support sparse dwarf forests, primarily because steep

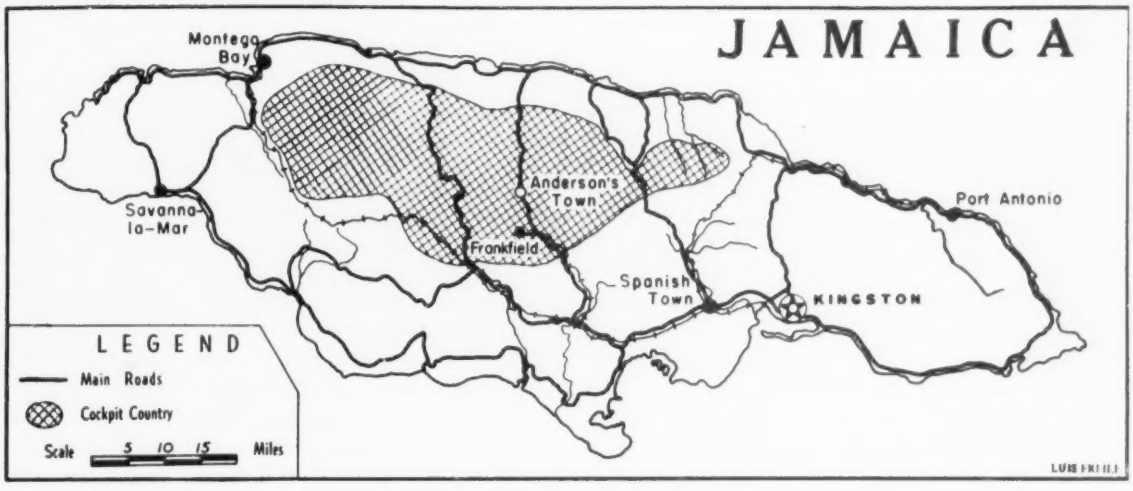

Fig. 8. The "cockpit country" of Jamaica. Note the general absence of a surface drainage pattern within the region and the paucity of transportation facilities, especially in the western two-fifths of the area.

slopes and excessive drainage in those locations preclude the development of large trees. On more favorable sites, taller, denser stands of trees are found. The lowlands and dolines support a somewhat more luxurious vegetative cover. These same lowlands and larger sinkholes are the centers of most of the agricultural activity of the region. Some valuable hardwoods, such as mahogany (*Swietenia mahogoni*) and tropical cedar (*Cedrela?*), are found in this karst area and are exploited to a minor extent.

Soils of the karst region of Jamaica range from thin, stony clays of the mogotes to well-drained, deep soils of the lowlands. Most of the soil cover contains little soil moisture, thus reflecting excessive drainage conditions. Within the arenas and sinkholes, reddish clay soils, locally called *Terra Rossa*, are found. These soils have the greatest utility of any within the "cockpit country." The *Terra Rossa* soil of the arenas and sinkholes is friable, relatively permeable to water, and red in color. Throughout the soil profile, bits of limestone rock prevail, which gradually grade downward in size and quantity from the "C" horizon (parent material), upward through the "B" horizon (subsoil), to the "A" horizon (topsoil). On the uplands, all soils are high in mineral content but low in organic matter; in contrast, the lowland soils contain quantities of organic matter and lesser amounts of minerals. Throughout the region only limited patches of soil are suitable for agricultural use.

The karst landscape of Jamaica is notably lacking in the development of economic pursuits which attract a large population. For all practical purposes, the only endeavor of economic importance is agriculture, and this is limited to isolated sinkholes and dolines because of restrictive soil, slope, and water conditions elsewhere. Agricultural products are confined to subsistence crops, of which yams, potatoes, beans, and corn predominate. Farms are small, semi-isolated, family-size acreages upon which the farmer's family lives as a more or less self-contained unit. The slopes of the dolines and mogotes support brush, which is utilized for charcoal manufacture. Occasional small patches of mahogany and cedar are cut and sold in nearby towns. Elsewhere these slopelands are cleared and utilized for cattle and goat pastures.

Population concentrations of this karst area reflect the location of the larger, more productive sinkholes of the region. Although a few population concentrations are present in the "cockpit country," when compared with the remainder of the island the karst region is practically void of people. The population of the region is overwhelmingly rural. A minimum number of urban concentrations are located just outside the region. Those villages that are present within the area exist solely as gathering points for farm produce and as minor service towns.

Transportation and communications facilities within the "cockpit country" are meager (Fig. 8). Scant economic opportunity and sparse population preclude the construction of a dense transportation network. No railroads traverse the region, and it is only recently that a main, hard-top highway has been constructed through the "cockpit country." Areas fringing the region on both the north and the

south are served by a fairly extensive road net, but the roads terminate at the "cockpits" and are replaced by a meager system of trails, which weave through the countryside. In the extreme northern portion of the karst lands a few secondary dirt roads are to be found.

Comparisons and Contrasts among Karst Regions

Many facets of the landscape of the karst lands of Puerto Rico, Cuba, and Jamaica are comparable, but a number of striking contrasts are noteworthy. A summary of obvious comparisons and contrasts follows. All three regions are underlain by a large, massive marine deposit of limestone. The limestones of Cuba and Puerto Rico are of Cretaceous age, while those of Jamaica are of Tertiary origin. The formations in Cuba are severely tilted, while those of Puerto Rico and Jamaica are essentially horizontal. Local relief varies from 1400 to 1500 feet within the Guaniguánicos of Cuba to 350 to 500 feet in Puerto Rico and the "cockpits" of Jamaica. The karst areas of Puerto Rico and Cuba are apparently in about the same stage of the erosion cycle, while Jamaica's karst landscape is not so far advanced.

The mogotes in all three areas are honeycombed with solution channels, galleries, and caverns, but here the similarity ends. In Cuba, for example, the tops are flat, mesalike formations, many being several square miles in extent. Puerto Rico, on the other hand, has bullet-shaped mogotes, characterized by a steep, western-facing side, with practically all the surface in slopes. Jamaica, much like Puerto Rico, is also composed of conical shaped mogotes, although they are somewhat irregular in profile. Cuba has fewer mogotes per unit area than has either Puerto Rico or Jamaica. The lowlands of the three areas, which include the sinkholes, dolines, or arenas (Jamaica), are similar in appearance to an inverted cone. In areas where the karst cycle has progressed further, flat-floored, elongate uvalas are present.

Large valleys with surface drainage and supporting rivers and streams of considerable size are present to a larger degree in Cuba. Puerto Rico has fewer such valleys and surface watercourses, and Jamaica is devoid of elongate stream valleys except in the fringe areas, notably in the south, where small, short streams make their appearance.

Climatically there is little variation between the three regions under discussion. All areas report 50 to 70 inches of precipitation per year, with the wetter months being from May through November. Higher elevation and exposed slopes receive somewhat more moisture than lowland rain-shadow regions. All stations in, and adjacent to, the karst regions report mean annual temperatures of between 70° and 80°F.

Extant natural vegetation of all areas of karst topography is quite similar and shows the ecological adjustment of vegetation to climate and soil conditions. Upon the slopeland and mogotes, sparse, low, shrubby forests are encountered, while the lower portions have a more luxuriant, taller, and more closely knit forest cover. Trees are both deciduous and evergreen species, which are more closely related to temperate varieties than to species in countries farther south. The close relationship of vegetation to slope and edaphic factors is exemplified by the sparse cover on the slopes and excessively drained areas as well as by the profuse growth in the many cracks and crevices of the soluble limestone.

Soils within all three regions are, of course, derived from limestone, and therefore each region has much in common with the others. Differences between the various regions are not so great as the many local variations found within each area. All soils are clayey in texture, permeable, some shade of red in color, and usually rapidly leached. Mineral content and organic matter are found in an inverse relationship to slope. The mogotes and slopeland are high in mineral content but low in organic matter, while the lowlands and dolines have high organic content but low concentrations of minerals. These lowlands have a soil much deeper and more mature than that of the mogotes. In general, all soils are relatively poor for agricultural purposes, the lowland soils being the most productive.

Agricultural pursuits vary slightly among all three regions with respect to quantity and type of crops grown; however, subsistence farming is the most important occupation carried on within all karst areas studied. Commercial crops include sugar cane, tobacco, some coffee in Puerto Rico, and minor amounts of fruits, largely grapefruit and pineapples. Sugar cane is by far the most important commercial crop grown. Commercial crops of Cuba and Puerto Rico cover a greater portion of the cropland than is the case in Jamaica, where there is practically no commercial production. Subsistence crops peculiar to a particular area include *frutos menores* in Puerto Rico, rice in Cuba, and yams and potatoes in Jamaica.

The few goats and cattle possessed by the local inhabitants are grazed upon the mogotes except in Cuba, where the greater local relief and high degree of slope preclude grazing activities in the hilly land. Within the Guaniguánicos of Cuba some

tourist trade is carried on because of the proximity to Havana. Locally the cutting and selling of wood and charcoal may be an important subsidiary occupation of the farmer in all three regions.

All three areas are overwhelmingly rural. Only a few small villages dot the area, rendering services to the local farming community. These urban clusters are somewhat larger in Cuba and Puerto Rico than in Jamaica, where almost no villages are noted; however, all three regions show larger urban concentrations adjacent to the karst lands. Here, as in the farming communities, practically all of the indigenous villages are located in the larger valleys and sinkholes. The fact that population densities are low except in locally favorable areas vividly points out the adverse conditions of topography, soils, and, to some extent, climate.

Low productivity, rough topography, and low population densities combine to produce a meager transportation and communication system. Hard-surfaced roads are at a premium. Those which are present have been built within the recent past and are constructed primarily to allow transit through karst regions rather than to serve the region proper. Secondary roads, although they are somewhat more abundant, are likewise conspicuous by their absence. Most transportation is by means of trails, and these transportation routes show a marked affinity for the more densely settled sections of the land. Many areas are even devoid of trails.

The karst lands of Puerto Rico, Cuba, and Jamaica possess a degree of geomorphic homogeneity which invites comparison of the three areas. As has been demonstrated, however, heterogeneity within and among them is as significant as are their similarities. Undoubtedly, certain features common to these karst areas are recognizable in other tropical karst regions. The inference is, therefore, that tropic karst areas everywhere possess certain like physical and cultural characteristics. The geomorphic likenesses have been well stated elsewhere. Further investigation is necessary to uncover other analogous aspects of tropical karst landscapes.

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6. R. Pico, *The Geographic Regions of Puerto Rico* (Univ. of Puerto Rico Press, Rio Piedras, 1950), pp. 143–44.
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Aristotle's Lantern

Our cover this month features an aboral (dorsal) view of the radial jaw parts of the purple sea urchin, *Arbacia punctulata*. The specimen was collected near Lewes, Delaware, and the photograph was made by William H. Amos, a research associate at the Marine Laboratories of the University of Delaware and instructor in zoology at St. Andrew's School in Middletown, Delaware. In addition to his teaching and research in zoology, Mr. Amos does photographic illustration, particularly in color, for books.

Concept of Energy in Mechanics

R. B. LINDSAY

Dr. Lindsay is dean of the Graduate School of Brown University, Providence, R.I., where he is also Hazard professor of physics and director of the Ultrasonics Laboratory. He was graduated from Brown University in 1920 and received his Ph.D. degree in theoretical physics from Massachusetts Institute of Technology in 1924. He was a fellow of the American-Scandinavian Foundation at the Institute of Theoretical Physics in Copenhagen in 1922–23; he then taught physics at Yale University until 1930, when he returned to Brown. During the past 2 years he has developed a general education course in physics for undergraduates, centered on the concept of energy.

THE well-nigh infinite variety of human experience is a great boon to the poet. It is also a sharp challenge to the scientist. The former finds in it a never-ending source of material for esthetic expression of moods and feelings. The latter is not happy until he has reduced it, or some portion thereof, to a semblance of order; it is only then that he feels he understands it. None but the philosophers pretend to know what understanding really is, and even they by no means agree. The merit of the scientist is that he has constructed a device which by concentrating attention on observed routines and regularities not only enables him to predict the occurrence of previously unobserved experience but also literally to create new experience on a vast scale. Pragmatically this has led to a steady expansion of the "known world" in much the same sense that geographic exploration expanded human knowledge of the surface of the earth, with the difference, however, that there is no known limit to the scientific creation of experience. It has served to increase the physical activities of human beings far beyond the wildest dreams of their ancestors. But more important still, it has provided an apparently boundless exercise for the human brain.

It is doubtless incorrect to talk of "the scientific method," though the term now has a well-established currency. Actually scientists employ many methods, but the essential power of them all lies in the invention of abstract concepts or constructs which embrace wide reaches of experience and in this sense may be said to be unifying in their nature. Such a concept, for example, is *mass,* without which it would be impossible to understand the relative motions of objects both great and small. This is a quantitative concept, so precisely defined that we are able by measurement to assign a numerical value to it in terms of specified units (that is, in terms of an arbitrarily chosen standard of mass) for every particle that comes within the range of our experience, whether it be a large-scale particle like a planet in the solar system or a small-scale particle like an electron in an atom. A qualitative concept, on the other hand, is illustrated by the notion of *wave*, familiar to everyone as a moving disturbance on the surface of water but describing a veritable host of phenomena involving the propagation of disturbances through continuous media—for example, sound waves, light waves, earthquake waves, and radio waves. Here the properties assigned to the concept *wave* in one context serve to apply to many others and thus exert an enormously fruitful and powerful unifying influence.

Of all unifying concepts in the whole field of physical science, that of *energy* has proved to be the most significant and useful. Not only has it played a major role in the logical development of the structure of science, but, by common consent, it is the physical concept which has had and still has the widest influence on human life in all its aspects. Under the prevailing misnomer "power," it is the stock in trade of the engineer and that which makes the wheels of the world go round. Everyone now knows that atomic (or more accurately nuclear) energy will either solve all the practical problems of the race in the future or effectively terminate its existence! More soberly, the interpretation of phenomena in terms of the transfer of energy between natural systems is the most powerful single tool in the understanding of the external world.

As is the case with many physical concepts, the germ of the idea of energy is hidden in the mists of antiquity. Man early learned the social significance of the fact that human life was impossible without somebody's labor, and this was well expressed by the author of Genesis when he has God exclaim to the sinner in the Garden: "In the sweat of thy face shalt thou eat bread." A large part of the history of the human race is the story of the

effort of the clever people to pass on this back-breaking work to others less clever than themselves, first to other human beings in the shape of slaves and then to domesticated animals, too dumb to realize their part in man's instinctive, if for a long time not clearly understood, search for the sources of energy to relieve him of toil. Eventually the clever ones discovered the possibility of diminishing the effort involved in labor by the use of mechanical devices like the lever, the inclined plane, and various forms of pulleys. These gadgets, which we now call machines, must have seemed to the ancients to be possessed of almost magic powers—they made it so much simpler to raise heavy weights, for example, or to give an arrow great speed.

The discoverers and users of machines doubtless observed very early that the advantage provided by a machine does not occur unaccompanied by a compensating disadvantage, that nature is not inclined to give something for nothing. It was found, for example, that to raise a given weight by applying to a pulley system a force much less than the weight, the speed with which the pulley rope is pulled must be much greater than the speed with which the weight is raised, or alternatively, if one wishes to pull with a low speed, the time for raising the weight with the machine is correspondingly increased. In other words, with the gain in ease of exertion in the performance of a given bit of labor with the use of a machine, there goes an inevitable loss in something, represented in general by the increase in the time required. This was recognized explicitly in the writings of Hero of Alexandria (*1*), who lived sometime between the second century B.C. and the third century A.D. One might have supposed that this peculiar principle of compensation, whereby a certain gain is always balanced by a corresponding loss, would have excited the interest of the Greek philosophers, who certainly enjoyed abstract speculation. However, there is no extant indication of any such concern; perhaps it was taken for granted that nature was bound to exhibit a certain amount of "cussedness" in spite of man's cleverness. Greek mythology took ample account of the jealousy of the gods at the inventiveness of mortals, as is illustrated by the story of Prometheus. In any case, this observation of the peculiar property of machines was one of the earliest recognitions of what modern science calls the principle of the conservation of mechanical energy, and it contains within itself a germ of the idea of energy.

Now energy is a physical concept and, as such, is a part of the logical structure of physics. We cannot hope to understand its true significance, let alone its unifying influence in the whole of modern science, without a brief examination of what a physical concept is. This in turn demands a description of the method of physics.

Laws and Theories in Physics

Physics is often referred to as an abstract science, and most people take this to mean that it is difficult, which may be accepted as true, though of slight help in understanding its nature. More important is the association of the idea of abstraction with physics in the sense that in his endeavor to understand experience, the physicist abstracts from the totality certain small regions for intensive study. Thus, from experience related to observed changes in the appearances of concrete objects, he abstracts that part best described by saying that the objects move. By concentrating attention on a relatively narrow field of experience, he believes that he stands a better chance of detecting order and regularity. This may be an illusion, but it has certainly led to success in a way which will shortly be made clear.

Choosing the motion of bodies as his field, the physicist is naturally led to initial simplification by picking out of all motions certain ones that seem to be the easiest to study. Notable among these are those involving the free fall of objects near the surface of the earth. It is natural to observe as many cases of this as possible and try to describe as simply as possible their similarities and differences. The confusion presented by the undoubted observation that, whereas most bodies when released fall to the earth, certain ones (for instance, properly inflated balloons) rise, is finally resolved by deciding on the further abstraction of restricting one's study to free motion when the surrounding air is removed as completely as possible—that is, motion in a vacuum. Then certain regularities at once appear—for example, that all bodies in such surroundings fall from a given height to the ground in the same time, irrespective of their size, shape, constitution, or apparent heaviness. Further and more sophisticated study indicates another regularity most easily expressed in mathematical form: that the distance of fall, starting from rest, varies as the square of the time, again independently of the nature of the body. The description of such a routine of experience, a pattern of observed behavior, is called a physical law. The law of falling bodies, Boyle's law of gases, and Ohm's law for electric currents are all illustrations.

A physical law answers the question: How do things appear to go in a given domain of experi-

ence when conditions are adequately controlled? It introduces order out of chaos and thereby breeds confidence with respect to order in limited domains of experience. Our interpretation is naturally an oversimplification. It all seems too easy: the physicist merely throws some apparatus together, performs a few experiments in which changes are observed and measurements made, and immediately detects order which he describes in terms of a law. If this were so, it should not have taken the human race so long to discover or invent the law of falling bodies, nor have required the patient mental toil and keen intuition of a genius like Galileo to elucidate it. Anyone with normal intellectual equipment and willingness to use it can make himself familiar with the meaning of a particular physical law, but only a person with unusually profound insight can discover one.

It is precisely at this point that the overwhelming significance of the physical concept emerges. A person faced with the problem of understanding motion—say even such an apparently simple thing as the free fall of a body—must first decide what it is that is worth while to study or to measure, what operations will most profitably reveal the regularity he would like to find. When he has finally decided on a certain operation as useful, he has effectively defined a concept, and it remains only to give it a name, so that it can be subsequently identified. For example, when he undertakes to match the varying positions of a ball as it falls to the ground with the corresponding varying positions of the hands of a clock, he has laid the groundwork for the definition of the concepts of linear displacement and time; henceforth when he uses the symbols x and t he knows exactly how to assign numbers to these in terms of experimental measurements and preestablished scales. This also permits him to express the contents of the observed relationship between the concepts, as thus operationally defined, in terms of algebraic equations, which then serve as very convenient shorthand expressions for the associated physical laws.

The thoughtful looker-on will doubtless complain that there is a lot of arbitrariness in this process. This is true! Too great a premium seems to be put on the cleverness of the concept constructor. And how can one ever be sure that the concepts are really the best ones, the right ones? The honest answer is that we cannot. In fact there is no meaning to the expression "the right concept." The imposition of order on our experience seems to be more readily accomplished through certain concepts than through others. Put in other terms, the concept builder is really constructing an ideal world in which the entities are his concepts, and his endeavor is to set the world of experience into one-to-one correspondence with this conceptual world. In so doing he is naturally tempted to go far beyond the mere creation of laws which appear to be a direct description of experience. He enters here into another realm, that of physical theory.

A physical theory has been likened to the mental construction which a detective builds in order to account for the crime he is investigating. Faced with certain more or less mysterious facts, he tries to imagine a train of circumstances which, if they were true, would account for the appearances and "solve" the crime. In similar fashion the theoretical physicist, faced with certain observations and the existence of well-established laws, constructs in his imagination a picture of a hypothetical world containing entities to which he can assign any properties he likes. He then sees what logical consequences he can draw from the postulated relations among these entities and their properties. His hope obviously is that among these consequences he will find some mathematical relations which, on suitable identification of the symbols with experimental operations, will correspond to the descriptive laws already discovered. If this hope is satisfied he becomes very happy. Of course he is made even happier if he is able to deduce from the hypotheses of his theory a relation which corresponds to a law which no one has ever discovered through experiment. If, on the carrying through of the appropriate test, the deduction is found to be verified, the satisfaction of the physicist with the theory is obvious: he is likely to think of it as highly successful; in fact, he may be pardoned for showing enthusiasm for the accomplishment, and his colleagues will join him. This is the high-water mark of success in physics—namely, the theoretical prediction of experience hitherto not obtained. When this is added to the ability of the theory to account for the existence of laws already established to describe the results of prior experiments, the physicist begins to feel that he has achieved what may be called an *explanation* of a certain domain of experience. He makes no claim regarding any quality of "truth" in the explanation. Nevertheless, once the concepts and postulates of the theory have led to laws identifiable with routines of actual experience, he has at his disposal a very powerful tool for the production of further experience and further verified knowledge in the given domain and, indeed, possibly in others. This is, in brief, what the physicist means by "understanding" the world about him.

An illustration will serve to clothe with flesh the dry bones of the preceding outline. We naturally turn to the theory of mechanics, since this is

the most famous of all physical theories and the one whose concepts are the basis of all other theories in physics. Its domain is *motion*, one of the most fascinating of all fields of human experience and one which we cannot avoid in our daily lives unless we wish to live like vegetables. To most people it seems a very dull business, but it has enthralled natural philosophers from Aristotle to Einstein as being the clue to the scientific understanding of all natural phenomena. There is no field of physics into which the concepts of mechanics have not permeated, and of all these that of energy has proved to be the most pervasive and influential.

Foundations of Classical Mechanics

The concepts of mechanics are fabricated out of our admittedly fuzzy and primitive notions of space and time, long the happy hunting ground of philosophers of all kinds. These are the categories or frameworks in which physical objects find their place and undergo their changes. As the simplest physical object which moves, the physicist invents the "particle," which like a mathematical point has *position* in a reference system and can change its position in time. Once started, the process of concept construction is limited only by the imagination and intuitive powers of the scientist. Change of position becomes *displacement*, and rate of change of position in time, *velocity*. But, since the velocity of actually observed particles on the earth's surface (for example, bullets, motorcars, and the like) is rarely observed to be constant, it seems necessary to introduce rate of change of velocity, or *acceleration*. One might go on and invent still further concepts such as rate of change of acceleration. But this is where the power of genius intervenes; it knows just when to stop!

The geometry of motion of a single particle, called kinematics, can be developed from the foregoing concepts more or less as Euclid's geometry of stationary position proceeds from his definitions, axioms, and postulates. Thus one can assume that a particle moves with constant acceleration in a given system of reference and proceed to draw consequences about the change of position with time. Examples of this sort of hypothesized motion are then sought in experience (and actually found!). But this sort of thing soon grows tiresome, and the pain of the boredom is heightened by the reflection that the most interesting motions which experience presents are those in which more than one particle participates. Here a new experiential demand appears. Particles in the shape of actual physical objects (even very small ones) seem to have the power of affecting each other's motion, and not all particles of the same size and similar appearance behave alike. Thus if two particles are tied together by a rubber band, which is stretched and released, the two particles in general do not move together with the same acceleration, in spite of what symmetry would dictate; particles do not behave simply as geometric points. This suggests the creation of yet another concept, that of mass, defined in such a way that the ratio of the masses of any two interacting particles is the inverse ratio of the magnitudes of the acceleration which result from the interaction. The choice of one particle as a standard unit mass thus makes it possible, in principle, to determine the mass of every other particle in the universe.

This definition and the accompanying implicit postulates constitute the whole foundation of the so-called Newtonian, or classical, mechanics. They suggest at once the value of the introduction of the concept of force, measured by the product of the mass of a particle and its acceleration, and provide of course for the principle of action and reaction. What is in many ways more important, they lead to far-reaching conservation principles. If we define the momentum of a particle as the product of its mass and its velocity, we can deduce from the hypotheses of classical mechanics the law that, if a system of particles moves subject only to its mutual interactions (that is, no external forces), the total momentum of the system remains constant in time. The momenta of the individual particles of the system may and generally will change, but this must happen in such a way that the net change for the whole is zero. This constancy in the midst of change has always proved to be a powerfully attractive point of view in any attempt to understand physical phenomena. So strong indeed is the human urge to extract from experience something that "stays put" long enough for close observation and study that we find the Greek philosopher Parmenides (in the fifth century B.C.) arguing that change is really an illusion. He must have been impressed (or depressed) by the apparently chaotic sequence of events in ordinary human experience and have decided that the only way to cope with it is to assume that there is no such thing as change, or at any rate to act as if this were the fact. He felt that this indeed is what men try to do when they invent names for things and so identify them continuously throughout the apparent flux of experience. This seems farfetched perhaps today, and most of us are probably inclined rather to look more kindly on the rival view of Heraclitus of Ephesus (about 500 B.C.), who insisted that *all* is change. But the complete acceptance of this attitude would make science as we know it impossible,

since we could never get a mental grip on anything before it became something else.

This brief excursion into Greek philosophy must not be taken very seriously. Nevertheless, it forces us to face a definite need which is met in modern science by the construction of concepts leading to elements of stability and constancy in the theoretical structure of the world. The great conservation principles of physics, of which the principles of the conservation of momentum and mass are important examples and the principle of the conservation of energy is without question the greatest, reflect this deeply felt need. From a practical standpoint they provide very potent tools for the solution of many problems in technical mechanics; looked at more philosophically, they imply the possibility of unifying vast reaches of experience under one common point of view.

The principle of conservation of momentum is exemplified in every game of billiards. A more practical example is in the recoil of a rifle when fired. A still more fascinating illustration, which has been fundamental for modern quantum physics, is provided by the Compton effect, in which a collision takes place between a photon, or particle of light, and an electron. The use of the principle enables the experimenter to explain the observed change in frequency of the scattered light.

The conservation of mass might seem to be a somewhat trivial matter. But it turns out to have very great importance in the flow of fluids, both incompressible and compressible. The increase in velocity of water flowing through a constriction in a tube over that in the part of wider cross section will be recalled by every reader; the explanation is the invariability of mass flow across any cross section of the tube. Once again, constancy in the midst of change!

But the conservation of mechanical energy holds the prime position in physical science, and it will be our task in the remaining pages to see why. It is first necessary to define what we mean by mechanical energy. This is the more important, since many of the popular references to the term give the impression that it is a kind of substance which can be stored in a barrel and drawn off through a tap! The precise definition of mechanical energy is a beautiful example of the search for useful concepts in physics.

Conservation of Mechanical Energy

Historically, the germ of the idea of energy is found in the notion of work, which is merely the measure of what may be called the spatial effect of a force on a particle. Thus the work done by a force acting on a particle during the resulting motion, assumed for simplicity to lie along a straight line, is defined to be the product of the average force and the displacement. For a given average force, the greater the displacement, the greater the work, and so on.

Now consider two particles, which we may label A and B, and suppose that there is a mutual force acting between them; that is, A acts on B with a force which is equal and opposite to that with which B reacts on A. If we apply the ordinary Newtonian law of motion to each particle (the force equals the product of mass and acceleration), we can readily calculate (either by very elementary or rather advanced mathematics—the result is the same, by some miracle which it would take far too long to explain!) the work done by the mutual force as the particles move relatively to each other. This work is not in general the same for the two particles in any given time interval, for unless the masses of the particles are equal they will not move the same distance in the same time. In fact, in general the particles behave quite differently with different accelerations and velocities. Nevertheless, if we *add* the two work expressions and make a little algebraic rearrangement, we obtain a rather remarkable result: in spite of the comparative complexity of the motions, there exists a very definite expression, containing the position coordinates and velocities as well as the masses and the mutual force of interaction, which remains *constant* during the motion.

This invariant of the motion is called the *mechanical energy* of the system of the two particles. It is made up of two parts. The first is the sum of the so-called kinetic energies of the two particles. The kinetic energy is the name given to the quantity formed by multiplying one-half of the mass by the square of the velocity (historically, the *vis viva* of Leibnitz). The second part is the so-called *potential energy* of interaction. In the rather common case where the force of interaction depends only on the separation of the particles, the potential energy also contains only this separation and certain constants (like the masses, for example). As the motion proceeds, the total kinetic energy will vary and so will the potential energy, but the sum will remain constant. It is the existence of this *constant* in the midst of the complex changes taking place in the system which constitutes the really important physical result of what might look like mere mathematical manipulation.

Once again the physicist simply cannot help but feel that this quantity which turns out to be an in-

variant of the motion is going to play an important role in mechanics. Hence, he baptizes it "energy" and proceeds to look for similar expressions in all sorts of other mechanical situations. Once the recipe has been clearly set up, it is not surprising that he finds what he wants and becomes happy over what seems to him a particularly simple interpretation of the motion of systems of particles.

The motion of a freely falling particle near the surface of the earth has long been one of the most fascinating illustrations. Here the earth itself is the other particle, and the interaction is the force of gravitation, that force which Newton was able to do so much with. The mass of the earth is so large and its velocity due to the interaction is so small that the total energy of the system reduces, to a good approximation, to the sum of the kinetic energy of the particle and the potential energy of interaction, which turns out to be proportional to the height above the surface of the earth.

If the particle is released from rest at a given height, its initial energy is all potential, and the conservation principle guarantees that this initial potential energy is the total energy for the *whole* falling motion. As the fall proceeds, the potential energy diminishes as the kinetic energy increases, the sum remaining equal to the total mechanical energy. When the particle strikes the floor or the ground, the potential energy has been reduced to zero (it is assumed that the particle can fall no farther), and the energy is all kinetic, again equal to the total energy and, hence, to the initial potential energy.

What happens now? This depends on the nature of the surface and of the particle. If they are both hard, the particle will bounce and travel vertically upward, losing kinetic energy and regaining potential energy. The conservation principle predicts that in this bounce it will ultimately reach the height from which it was originally dropped, before it has lost all its kinetic energy. Actually, in our experience, it never quite does this—a rather disconcerting apparent disagreement with the principle. As a matter of fact, if the surface on which the particle falls is rather soft, the particle may not bounce at all but will appear to lose all its kinetic energy without appearing to gain any corresponding potential energy. The so-called "constant" energy here would then seem to be an illusion, and the physicist is placed in a decidedly embarrassing situation. Of course, we realize that he must have been able to wangle himself out of it, or we would have small excuse for talking at all about the concept of energy. By one of life's ironies, it is precisely an apparent difficulty of this kind which has ultimately led to an even stronger conviction of the value of the concept. This is such a vitally significant part of the whole story that we shall linger over it a bit in terms of another illustration.

Imagine two billiard balls of the same mass suspended by parallel strings of equal length from a high ceiling, so that when hanging freely they just touch. If they are pulled apart and let go in the same vertical plane, they hit and bounce back. Careful observation confirms the fact that the total momentum of the system of two balls immediately after the collision is the same as that just before—in other words, there is conservation of momentum, or, as we may correctly say, the balls exchange momenta on collision. If the principles of mechanics provide a successful description of the motion of particles, this is what we have to expect, since the conservation of momentum does not depend on the precise nature of the force of interaction of the two particles. In fact, even if the balls were putty balls of equal mass, instead of being the hard, elastic spheres which make the game of billiards possible, the result of the collision would still agree with the principle of conservation of momentum! It is true that in this case the two balls would come to rest and stick to each other, but the momentum of the system immediately before and immediately after collision would still be equal. Indeed, it would be zero at both times—afterward, because neither ball has any velocity left, and before, since though the balls are moving, their momenta are equal in magnitude and opposite in direction and, hence, add algebraically to zero.

How stands it now with the principle of the conservation of energy in the collision of the billiard and putty balls? Since the hard billiard balls bounce in lively fashion, it would appear that the principle is maintained, but careful inspection shows that the balls, after collision, do not swing out as far as the positions from which they were released. This in itself arouses suspicion which becomes indeed open disbelief when we experiment with the putty balls and find that when they hit they stick together and stop moving completely—the original kinetic energy disappears utterly, and no obvious potential energy appears to compensate for the loss. Of course, one reflects, the balls are deformed on collision, and hence the work done in the deformation may be treated as coming from the lost kinetic energy. Closer examination shows that this is not wholly true—that, in other words, the work done is less than the loss in kinetic energy and there is a net loss in total mechanical energy.

The melancholy fact emerges that in every actual case of the interaction of particles ample enough

for us to examine them with our senses, the principle of the conservation of energy breaks down, or, put otherwise, the concept of energy does not appear to be a useful one. Is not this a paradoxical situation? The cynical observer who approaches science with a rather jaundiced air is likely to make much of this "failure." Even the serious student who knows that physical science somehow "works" in a practical sense in technology and believes that it ought to be logically unassailable also, is likely to feel uncomfortable in the face of the difficulty. He notes that the conservation of momentum describes with ease situations in which the mechanical energy idea breaks down. Why then do we not concentrate our attention on momentum as the really useful constant in the mutual motion of particles; why seek another one?

This reminds us of the celebrated controversy between Descartes and Leibnitz in the 17th century. It will be recalled that Descartes felt very strongly that God had arranged things so that the total momentum (called by him "quantity of motion") of the universe is constant, and all that we can do is to produce changes of momentum by transfer from one particle to another when interactions take place. Hence, Descartes naturally assumed that the true measure of force is found in the change of momentum produced in a given time. This view was vigorously combated by Leibnitz, who published in 1686 a brief paper in the *Acta Eruditorum* (Leipzig) calling Descartes' view a "perversion" of mechanics. Leibnitz had no difficulty convincing himself that the "true" measure of the efficacy of a force is the product of the mass and the square of the velocity, or what he termed the "*vis viva*" or living force (that is, double what we call the kinetic energy).

The controversy, superficially considered, was dismissed by d'Alembert in his famous treatise on mechanics of 1743 as a confusion in terminology. And, indeed, we may measure the cumulative effect of a force by both its integrated effect over *time* (that is, the change in momentum it produces) and its integrated effect over *space* (the change in kinetic energy it produces). Both are equally valid measures, and only convenience dictates a choice between them. Nevertheless, from a modern standpoint we are entitled to see in the controversy the germ of the argument about which is the better principle on which to base the application of mechanics to all physical phenomena, that of conservation of momentum or that of conservation of mechanical energy. By an irony of fate, the principle advocated by Descartes, whose physical theories in general are not conceded by modern scientists to have been very effective, is the one which always works in the large-scale interaction of bodies, whereas the conservation-of-energy principle breaks down, in part, in the simplest of examples. And yet it is the energy principle which has triumphed. Once more we ask, why is this?

Success from Failure

The very success of the momentum principle suggests its possible ultimate lack of utility in the logic of physics; its very independence of the nature of the forces of interaction raises no questions about them and obviously answers none; its role therefore is a highly restricted one, in spite of the fact that certain practical problems are illuminated by it. On the other hand, the very failure of the energy principle stimulates the quest for the reasons why; it raises questions about the nature of the interaction forces which cry out for answer, and it guarantees the experimental search for other physical phenomena besides motion accompanying the interaction of observable particles. When these are found, in the form of heat, sound, light, electricity, and so on, the stage is at once set for the rehabilitation of the energy principle by the generalization of the meaning of the concept of energy to include other forms besides the kinetic and potential energy of directly observable particles. To the superficial observer this might appear as a dubiously honest scheme to save a point of view which has certain attractive features but does not really succeed. In the actual event it has provided the greatest unifying influence in the whole of physical science, for it has vastly extended the scope of the theory of mechanics to domains of phenomena in which no motion is observed to take place, or in which, if motion does take place, instruments of the greatest precision are needed to detect it. It is not always the immediate successes of the physical theory which count; its failures may prove more important in the long run.

There exists no more striking illustration of the fact just mentioned than the way in which the concept of energy, in spite of its obvious inadequacy in the large-scale, purely mechanical form, has in the course of time permeated the whole domain of physical science. In our time it dominates not only practical mechanics but also the vastly more extensive realms of thermodynamics, the electromagnetic field, and statistical mechanics. Thence it reaches out to touch practically every form of activity of living things. Truly, without exaggeration it may be termed the premier scientific concept.

Reference

1. *Mechanics II* Nos. 21–26. See, for example, M. R. Cohen and I. S. Drabkin, *Source Book in Greek Science* (McGraw-Hill, New York, 1948), p. 230.

Control of Screw-worm Fly by Atomic Radiation

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AN understanding of the life history, habits, and population dynamics of the screw-worm fly, together with knowledge of the effects of atomic irradiation on genetic material in insects, has led to a new promising way to control or eliminate the screw-worm fly in certain areas. The screw-worm fly, *Callitroga hominivorax* (Cqrl.), is a destructive parasite of livestock in the southern areas of the United States. The method of control involves the release among the wild population of male flies that have been made sexually sterile by exposure to gamma rays. This article is an account of the research that has led to this unique method of insect control.

Biology and Economic Importance

The screw-worm fly (Fig. 1) is about three times as large as the common house fly. It deposits its eggs (Fig. 2) on wounds of warm-blooded animals. After 12 to 24 hours, about 200 tiny larvae hatch from each egg mass. The larvae (Fig. 3) feed on the tissues of the host for about 5 days. When fully grown, they are over ½ inch in length and about ⅛ inch in width. They then leave the wound to pupate (Fig. 4) in the soil. After 8 days to several weeks, depending on prevailing temperatures, the adult flies emerge. Mating takes place on about the third day, and eggs are deposited about 1 week after the emergence of the fly. The complete generation from egg to egg during summer months ranges from 3 to 4 weeks.

Screw-worm flies disperse widely by flight; they have been shown to disperse at least 9 miles (*1*). A related species, *Phormia regina* Meig., is capable of flying at least 28 miles (*2*).

After an animal is infested, the wound becomes increasingly attractive for oviposition. Consequently, multiple infestations result (Fig. 5), and several thousand larvae may be present in the wounds. Unless such infested animals are found and treated promptly, they will be killed in a week to 10 days. Death of the host is caused by consumption of tissues by the larvae and shock resulting from the loss of blood and lymph from the infested wound.

This insect is the most destructive pest of livestock in the southwestern and southeastern states. Losses are most severe in domestic animals, particularly cattle, sheep, goats, swine, and horses. However, the pest also attacks deer, rabbits, coons, opossums, and other wild animals. Infestations may also occur in man, but fortunately rather infrequently. When they do occur, there may be serious consequences because the attack is most commonly in the nasal passage, and treatment to destroy the larvae is very difficult.

Entomologists in the U.S. Department of Agriculture have conducted research on the pest for many years. Much information has been obtained on the life history and ecology of the parasite and on methods of treating wounds to prevent infestations or to destroy the larvae in infested animals.

Several excellent wound treatments have been developed. The most effective material now in use by stockmen is a smear known as EQ-335. This composition, containing lindane and pine oil, will prevent infestations in wounds and will destroy larvae already present. The newly hatched larvae cannot penetrate sound skin. However, any break in the skin may lead to an infestation. The most common causes of wounds suitable for attack by screw-worms include accidental injuries, shear cuts, tick bites, fighting, and surgical operations. In addition, new-born animals are particularly susceptible to screw-worm attack in the navel before the navel-cord attachment site is healed.

Ranchers in screw-worm areas must be constantly alert during the warmer months of the year, when screw-worm flies are most active, to find and

treat infested animals before they are destroyed by the parasite. In many areas, particularly in the open ranges of the Southwest, livestock production would prove unprofitable if range riders were not employed to find and treat susceptible or infested animals.

The insect survives the winter in the southern parts of Texas, Arizona, and California. It is also a year-round parasite in much of Mexico and Central and South America. It also overwinters in Florida. Each spring and summer it spreads northward several hundred miles from the overwintering areas. Through shipment of infested animals in the early spring, the parasite may also become well established in northern areas and cause severe losses before it is killed out by cold weather.

The total loss caused by the screw-worm varies from year to year, but it is conservatively estimated that the average annual loss to the livestock industry amounts to $25 million.

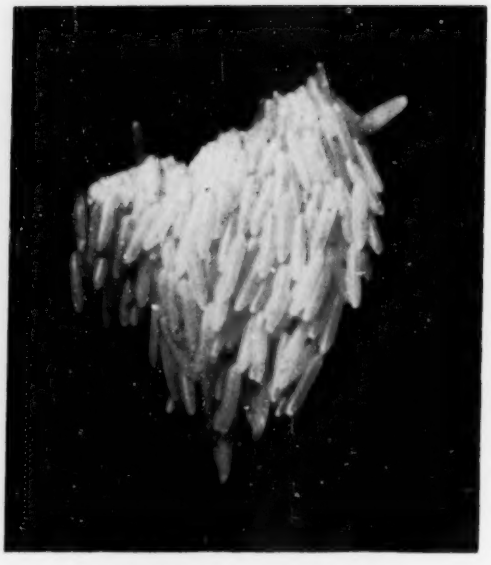

Fig. 2. Egg mass of screw-worm fly.

Basis for Considering the Feasibility of Releasing Sterile Males

Proper livestock-management practices and wound treatments keep losses down, but they do not solve the screw-worm problem. Other methods of control have been tried in order to reduce losses further, including extensive fly-trapping and community-wide animal-inspection programs. However, these methods have not proved practical. Not all infested domestic animals, especially on open ranges, can be found and treated. Even if all domestic animals are treated, the many wild animals that become infested serve as reservoirs for the parasite.

As pointed out by Lindquist (*3*), ecological studies have indicated that the number of flies even in areas of high infestation is very low in comparison with that of most insect species. Moreover, during winter months, the overwintering area is restricted and the fly population is greatly reduced. It has been estimated that the number of flies produced per week during the winter in Florida would be likely to average less than 100 per square mile. The low population density suggested the idea of controlling the insect by releasing more sexually sterile males than the number of fertile males that exist in the natural population.

Fig. 1. Female screw-worm fly.

It has been well established that sexual sterility can be induced in insects by exposure to x-rays and gamma rays (Runner, *4*; Muller, *5*; and others). A method of rearing the parasite on an artificial medium consisting of ground meat and blood was developed by Melvin and Bushland (*6*). On the basis of these developments, a research program was undertaken to test the feasibility of employing sexually sterile males to control the screw-worm. The decision to conduct this research was influenced by the encouragement and suggestions of H. J. Muller, noted geneticist, when I submitted the proposed program to him in 1950.

Laboratory Investigations

Exploration of the problem was undertaken by and under the direction of R. C. Bushland, entomologist with the U.S. Department of Agriculture at Kerrville, Texas. The findings in the laboratory, which have been published (*7*) may be briefly summarized as follows.

Studies with x-rays, and later with gamma rays, from a radioactive cobalt-60 source provided by Oak Ridge National Laboratory showed that exposure of screw-worm pupae 5 to 7 days old to approximately 2500 roentgens resulted in complete sterility of the male flies that subsequently emerged. A dosage of 5000 roentgens produced sterility in females. Exposure to gamma rays at dosages up to 20,000 roentgens did not seriously affect the vigor of the flies, although the average length of life was reduced somewhat. When sterile males were placed in cages with normal unirradiated females, mating took place and the females produced only sterile eggs. Further tests showed that such females continued to produce infertile eggs throughout their life span, which is normally about 2 to 3 weeks. Therefore, when a sterile male mates with a normal female, the effect is equivalent to destruction of the female.

The most encouraging feature of the laboratory studies was the demonstration that the sexual vigor of the irradiated males was not greatly reduced. Normal females were placed in cages together with irradiated and unirradiated males in various ratios to test the sexual vigor of the males or discrimination on the part of the females, or both, in matings with the two kinds of males. The ratio of sterile to fertile egg masses was almost the same as the ratio of irradiated to unirradiated males in the caged population. For example, if 10 normal females, 10 normal males, and 90 irradiated males were present in a caged population, about 90 percent of the females deposited sterile egg masses. Another point of practical significance was the indication that the presence of irradiated, sterile females did not adversely affect the results. Therefore, if a release program were undertaken, it would not be necessary to separate the females from the males, a costly undertaking.

Fig. 3. Fully grown larvae of screw-worm fly.

Fig. 4. Pupae of screw-worm fly.

Theoretical Possibilities

The laboratory investigations established that the basic principles for successful control of the screw-worm by releasing sexually sterile males were sound. The population decline each generation which theoretically might be expected from a release program in which sterile males initially outnumber fertile males is shown in Table 1, as previously published (*8*). It is emphasized that these figures are theoretical, but if we assume a maximum effect of released sterile males, the population decline would be rapid and dramatic.

The example assumes that biotic factors are such that the population is stabilized at a constant level. In other words, an assumed fly population of 1 million females and the same number of males, in the absence of any control effort, would produce 1 million females and 1 million males to replace the parent population that dies out from old age, predation, and other causes. In this hypothetical case, the initial release rate of 2 million sterile males results in a ratio of two sterile males to one fertile male. It is further assumed that the released males compete fully with the normal males in mating with the normal females in the population. In such event, two-thirds of the reproductive capacity of the population will be destroyed. Then, if we assume a maximum population decline, the population of virgin females in the second generation will only be one-third of that in the first. Consequently, the continued release of males at the initial rate will result in a ratio of six sterile males to one fertile male. This will cause an even more rapid

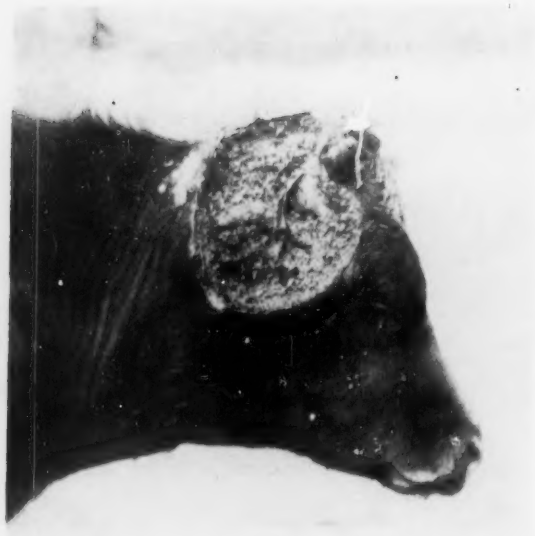

Fig. 5. Wound on a steer, heavily infected with screw-worms.

decline in the third generation. By the fourth generation, or in about 4 months, the screw-worm population will be wiped out. It is recognized that, in considering the potentials of the sterile-male approach, we cannot necessarily expect a maximum population decline. However, theoretically, if the decline is no greater than 25 percent of the theoretical maximum, eradication should still result in about six or seven generations.

Early Field Investigations

The laboratory findings and theoretical calculations were sufficiently favorable to indicate possibilities that the screw-worm fly might be eradicated by release of a preponderance of sexually sterile males among the wild population. It was necessary, however, to test the procedure in field experiments before its feasibility could be determined. Success would be dependent on a number of important factors. Precise information was needed on the number of screw-worm flies in the wild population. If the population density was too high, the cost of rearing and releasing a dominating population of sterile males would be prohibitive. It was also necessary to establish that the reared and released, irradiated males would disperse and compete successfully with the wild males. Early field experiments were conducted by A. H. Baumhover, A. J. Graham, and others in the Entomology Research Branch.

Since personnel and facilities were limited, it seemed desirable to conduct such experiments on a small island. The only small, somewhat isolated islands harboring screw-worms in the United States were a group off the west coast of Florida in the vicinity of Fort Myers.

The 15-square-mile island of Sanibel was chosen for these tests. This island is separated from the Florida mainland by a water barrier about 2 miles wide. Studies employing goats as host animals indicated that the screw-worm population was at least as high as the average for the State of Florida during the winter months, and perhaps higher.

In order to obtain an estimate of the natural population on the island, screw-worm flies from larvae reared on host animals that had been made highly radioactive with phosphorus-32 were released on the island. Egg masses deposited by these flies were sufficiently radioactive to be identified. The ratio of radioactive egg masses to those deposited by the natural population indicated that the natural population in each generation was probably less than 100 flies per square mile.

Sterile male screw-worm flies were then released at the rate of 100 per square mile, per week. This rate of release resulted in a 4/1 ratio of sterile to fertile egg masses collected on host animals. Continued weekly releases for 3 months reduced the natural population to a low point, but eradication could not be demonstrated. There was good evidence that a few fertile females previously mated with fertile males migrated to the island from nearby islands and from the mainland. It was concluded that the success of the method could be

Table 1. Theoretical population decline in each subsequent generation when a constant number of sterile males are released among a natural population of 1 million females.

Generation	Number of unmated females in area	Number of sexually sterile males released	Ratio of sterile to fertile males competing for each female	Assumed percentage of females mated to sterile males	Theoretical population decline of fertile females
1	1,000,000	2,000,000	2:1	66.7	333,333
2	333,333	2,000,000	6:1	85.7	47,619
3	47,619	2,000,000	42:1	97.7	1,107
4	1,107	2,000,000	1,807:1	99.95	Less than 1

Fig. 6. Method of rearing screw-worm larvae.

demonstrated only by conducting an experiment on a small, completely isolated island that would not be within range of migrating flies from other areas.

Eradication Experiment on Curaçao

In 1954 an opportunity was presented to conduct an eradication experiment on the island of Curaçao in the Netherlands Antilles. This island harbored a high population of screw-worms, which were causing heavy losses among goats and other domestic animals. The veterinary service on the island requested information on methods of control, and a cooperative program to attempt eradication was arranged by the U.S. Department of Agriculture and the Netherlands Antilles Government. The nature and results of these investigations, reported by Baumhover *et al.* (*9*), are briefly summarized here.

The island has an area of 170 square miles. It is 40 miles from the nearest land, which practically precludes the migration of screw-worm flies from other areas. Studies were conducted for several months to obtain information on the natural population density on the island. Host animals were exposed at 11 locations, and daily records were made on the number of egg masses deposited on them. Prior to the release of sterile males, over 99 percent of the egg masses deposited were fertile. Sterile males were released on a portion of the island for several weeks at the rate of 100 per square mile per week. The ratio of sterile to fertile eggs collected indicated that it would be necessary to release several hundred sterile males each week to achieve a dominant population of sterile males.

The eradication effort was started on 9 August 1954. It was decided that about 400 sterile males would be released per square mile each week. The screw-worm larvae were reared at the Orlando, Florida, laboratory (Fig. 6). Pupae were exposed to a radioactive cobalt source (Fig. 7) described by Darden *et al.* (*10*). The rate of exposure was 7500 roentgens. At this dosage, not only are both male and female flies sexually sterile, but the females are incapable of producing eggs.

Irradiated pupae were placed in special paper-

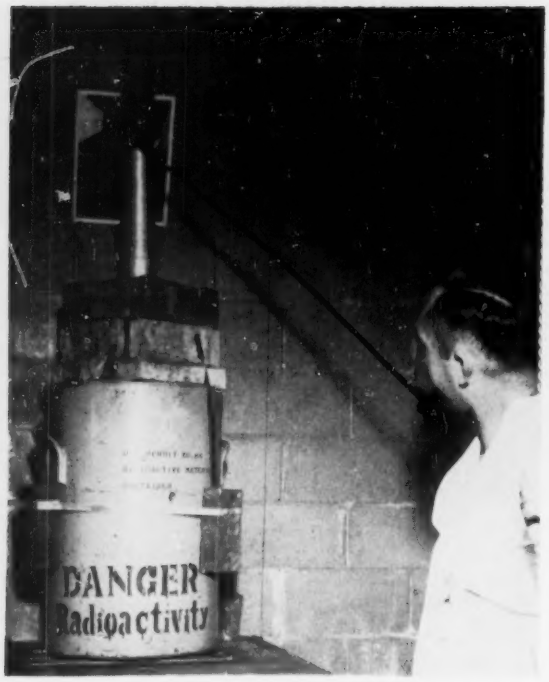

Fig. 7. Cobalt-60 source used to irradiate pupae of the screw-worm fly.

bag containers (Figs. 8 and 9), transported by commercial airlines to Curaçao, and released from a small aircraft. Releases were made twice each week. Fly drops were made at 1-mile intervals. Sterile females were also liberated, since separation of the sexes was not practical. Susceptible host animals were located in 11 pens well distributed on the island. Eggs were collected daily, and the rate of sterility was determined. Since the sterile females released were incapable of producing eggs, egg masses collected were from females in the natural population.

Table 2. Record of fertility of screw-worm fly eggs and of the decline in the number of egg masses in the screw-worm-eradication experiment on Curaçao.

Weeks after start of experiment	Number of egg masses		Percentage of sterile egg masses
	Fertile	Sterile	
1	15	34	69
2	17	38	69
3	17	36	68
4	10	37	79
5	7	42	86
6	3	23	88
7	0	10	100
8	0	12	100
9	0	0	

Data showing the number of fertile and sterile egg masses collected on the host animals each week following the appearance of sterile egg masses are given in Table 2.

The number of screw-worm flies in the natural population could not be determined accurately, but it is believed that the release of 400 sterile males per square mile, per week resulted in a ratio of about three or four sterile males to one fertile male. During the first week, 69 percent of the wild females deposited infertile eggs. As expected, this percentage remained about the same for 3 weeks. This is about the minimum time required to produce a new generation. By the fourth week there was a trend toward a higher percentage of sterile eggs. During the sixth week a marked decrease in wild population was indicated. During the seventh week, which may be regarded as the beginning of the third generation, the natural population had declined to such a low point that no fertile eggs were collected in the sample taken. Some fertile eggs would probably have been taken if more animals had been exposed and if a larger number of egg masses had been collected. However, the population of sterile males was so high in proportion to the population of fertile males that the chances for a fertile mating were exceedingly slim. From the ninth to the 13th week no egg masses, either sterile or fertile, were collected. One small, infertile, atypical egg mass was taken in the 14th week, and another in the 15th week. These small egg masses may have been deposited by released females which

Fig. 8. Flies from irradiated pupae were allowed to emerge in special paper bags, in which they were held until they were released.

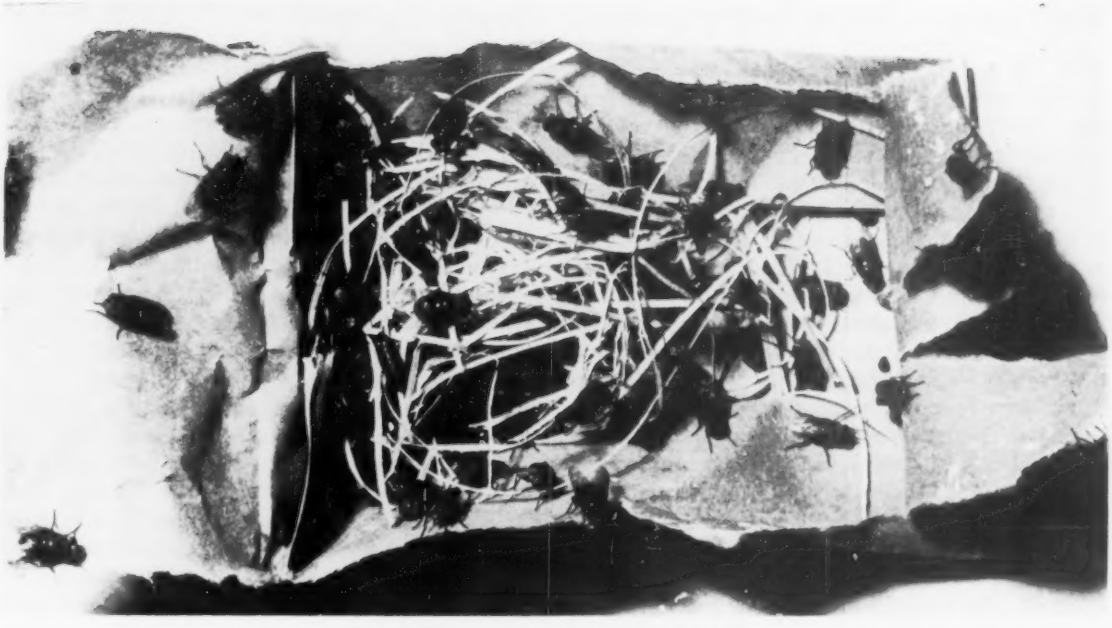

Fig. 9. Flies in one of the special paper bags.

by chance had received less than the expected 7500-roentgen dosage. It is also possible that, out of the many thousands of irradiated females released, some may have succeeded in regenerating egg-producing cells before they died. Thereafter no eggs of any kind were collected, although susceptible host animals were exposed through the 20th week.

In addition to data on fertility of egg masses, reports of infestations in the domestic animals were obtained from the livestock owners. No screw-worm attacks were reported in livestock after the ninth week; this confirmed the data secured on the experimental animals.

Early in January 1955 it was concluded that complete eradication had been achieved, and the experiment was terminated. According to egg-collection data and the absence of screw-worm cases, virtual eradication was achieved during the third month, or after about three or four generations of exposure to the sterile males. However, releases of sterile males were continued for about 2 months longer to be certain of complete eradication. No screw-worm cases on the island were reported up to February 1957.

It is interesting to note that the rate of population decline in the eradication experiment in general agreed with the theoretical calculations given in Table 1. The theoretical figures predicted elimination by about the fourth generation, and actual elimination of the pest was probably achieved by this generation.

Possibilities of Further Application

The success of the eradication program on Curaçao has stimulated great interest by livestock growers in having the screw-worm eradicated in the southeastern United States. The infestation in the Southeast now survives from year to year because of a favorable overwintering area in the Florida Peninsula. The infestation in the Southeast did not exist until 1933, when it became established through shipment of infested livestock from the Southwest. It is believed that if the insect could be eliminated from the area, and if measures were taken to prevent reintroduction through shipment of infested livestock, the area would remain free of the pest. Screw-worm flies from the Southwest are not likely to spread naturally as far as Florida in one season, and the insect normally does not survive the winter in the area between south Texas and the Florida Peninsula.

Since completion of the eradication experiment on Curaçao, research by the U.S. Department of Agriculture's Entomology Research Branch has been intensified. The Florida livestock owners have been cooperating in this expanded program. The purpose of this research is to improve methods of rearing and detecting low populations of the insect to make them economically feasible for larger areas. The overwintering area for the Southeast infestation comprises about 50,000 square miles. An eradication program employing the same release rate

as that on Curaçao will mean the release of 20 million sterile males per week. Since an equal number of females will be produced, and to allow for some breeding stock and some mortality in the pupal stage, it will be necessary to rear about 50 million screw-worm flies per week. For a fly-rearing project of this size, approximately 75,000 pounds of meat will be needed each week. A large and special rearing plant will be required. A tentative plant design has already been prepared with the assistance of the U.S. Army Chemical Corps at Fort Detrick, Maryland. A fleet of about 30 small aircraft will be needed to distribute the flies. Special cobalt-60 sources will be necessary to irradiate the pupae. Much manpower will be required to carry out the program. The release of sterile males should be continued for at least 2 years, if necessary. It is apparent that a program of this kind will be a huge undertaking.

The research personnel of the Department of Agriculture are confident that eradication can be achieved. The cost of such a program has not been accurately estimated, but it is believed that a 2-year eradication program would cost about $9 million. Since the losses caused by the pest in the Southeast have been estimated at no less than 10 million dollars each year, such a program appears to be justifiable from an economic standpoint. Adequate measures to prevent reintroduction of the pest from the Southwest through shipment of infested animals pose problems that need careful study. When the research program currently under way is completed, probably during 1957, the U.S. Department of Agriculture, the states having an interest in such a program, and the livestock industry will undoubtedly consider all aspects of the problem and decide whether or not to recommend that an eradication program be undertaken in the Southeast.

Use of Technique for Controlling Other Insects

Some thought has been given to the possibilities for controlling other insects by releasing sterile males (*8*). It is obvious that the method will not be economically feasible for most insects. Most species occur in such great numbers that it would be too costly to rear enough insects to release a dominant population of sterile males. Methods of rearing many insect species have not been developed. Many insects do not fly, or they have such a limited flight range that released males could not be distributed adequately to compete with the fertile males.

A number of other limiting factors exist among other insects. However, on the basis of current knowledge, the technique is worthy of study. For example, further research might show that the method could aid in the eradication of Mediterranean fruit fly infestations of the type now in Florida, which are now being eliminated by chemical methods. The Hawaii laboratory of the Entomology Research Branch has developed economical methods of rearing this insect, and preliminary studies have shown the sterile-male technique to be sufficiently promising to warrant further consideration. Scientists in Africa have shown interest in the possible application of the technique for eliminating the tsetse fly from certain areas after first reducing the existing population to a low point through the use of other control measures.

Since most insects are present in large numbers, the successful use of sterile males to eliminate well-established infestations can be expected only after the natural population has been reduced to a point where a dominating sterile population can be released and maintained until elimination is achieved. The method might also prove useful as a means of eliminating a newly established infestation if a great preponderance of sterile males could be released initially and maintained before the population increases and spreads.

Much research will be required before the limitations and potentialities of the technique can be determined for any specific insect. Such research should include studies on mating habits of the insect and studies to determine whether sexual sterility can be achieved without adversely affecting the male's sexual vigor and length of life. Methods of rearing the species in large numbers and a practical way to release and distribute the insect must be developed. Such research should be encouraged on highly destructive species which conceivably might lend themselves to self-destruction by the unique sterile-male technique.

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BOOK REVIEWS

Rockets, Missiles and Space Travel. Willy Ley. Viking, New York, 1957. xv + 528 pp. Illus. $6.75.

This book is a revised and enlarged edition of Willy Ley's book by the same title published in 1951. However, there is one noticeable difference—projects suggested in 1951 are now becoming reality!

Ley is probably the best known exponent of the developing science and art of rocketry and space travel in the world today. He has used his long experience and interest to write a momentous volume that is packed full of information, charm, and speculation. The first few chapters of the book discuss, in an inductive manner, the historical development of the art of rocketry from the earliest until modern times.

The development of the liquid-fueled rocket took the art from the amateur into the hands of the engineer. The impetus given to rocketry by the use of long-range rockets, such as the V-2 to bombard England, the rocket fighter planes of Germany and our own rocket planes that seem to break a speed record every year, and the high-altitude atmospheric research rockets just naturally had to culminate in the satellite program. Project Vanguard for the International Geophysical Year, which plans to launch orbital satellites for observational and experimental purposes, has excited more interest and enthusiasm than any other single project in our generation. The amazing thing about the development of rockets is that in the 1920's and 1930's each step known today was projected—and almost in the order of their present development. Following the orbital satellites, we may expect the manned space station. The latter permits flight to the moon, Mars, and Venus if used as a fueling station. Fortunately, 90 percent of the effort to achieve space flight will have been accomplished, once we have the manned space station.

A voluminous appendix contains additional articles and engineering data on rockets, astronautics, and so forth. Unfortunately, the comprehensive fold-out "Characteristics of the earth's atmosphere" was omitted from the present edition. Thirty-one carefully selected plates, in addition to numerous line drawings, diagrams, and graphs, illustrate the book.

Ley's book is so complete and well-rounded that I would like to recommend that he should not attempt another revision but permit the present volume to become a standard reference book, and then every 5 years write a companion volume(s) to bring rocketry up to date. At the rate that rocketry has been advancing it should be an easy job to fill a book every 5 years just keeping up with the world.

This book is the *definitive* book about the subject, for the interested layman, the amateur rocket man, and the professional engineer who wants to see where *he* is going!

THOMAS S. GARDNER
Hoffman-La Roche, Inc.

Medical Department, United States Army, Surgery in World War II. *General Surgery*, vol. II. 1955. 417 pp. Illus. $4.25. *Orthopedic Surgery in the Mediterranean Theater of Operations.* 1957. 368 pp. Illus. $4. *Orthopedic Surgery in the European Theater of Operations.* 1956. 397 pp. $4. Office of the Surgeon General, Department of the Army, Washington (order from Supt. of Documents, GPO, Washington, 25).

Three more volumes have recently been added to the already massive, yet incomplete, medical history of World War II. The volume on general surgery is a special one in that it is concerned not alone with surgery performed in forward medical units but particularly with the management of emergency cases—mostly abdominal injuries—which, because the individuals were nontransportable, required attention almost where they fell. It is an account of 3154 cases of abdominal injuries combat incurred in the Mediterranean Theater of operations, the largest such series to be studied and analyzed in such detail.

It is obviously impossible in a short space to discuss this book in detail, especially since much of the material in this and the other two volumes under review is of interest primarily to members of the medical profession. However, a few general remarks are perhaps in order.

One of the lessons which apparently has to be relearned in every war is that there is no adequate substitute for battlefield experience for the military surgeon. Thus the combat theaters of World War II provided a vast testing area for weapons and tactics as well as for procedures and supplies. It is within this framework that an appraisal of the work of the medical department of the Army must

be viewed. Thus, is was quickly recognized that medico-military doctrine in effect in 1942 was already outmoded, and it is a tribute to the front-line surgeons that their minds, as well as their hands and fingers, were flexible and nimble so that they swiftly learned lessons from injuries produced by new weapons of warfare and new tactical situations. Thus, new drugs, improved methods of anesthesia, the wholesale use of blood transfusion, together with swift front-line surgery and rapid evacuation, all contributed to an impressive record of recovery among men so seriously wounded that in previous wars, most of them would have died.

The two books on orthopedic surgery discuss battle injuries involving bones and joints. This type of injury represents one of the most common types of war wound; indeed, 70 percent of battle casualties in the Civil War, World War I, and World War II involved the extremities. Here again one of the significant lessons derived is the importance of major surgical intervention at the earliest possible moment, coupled with swift evacuation to the rear.

Errors, as well as successes, are recorded in these well-written and well-produced books. It may be said in conclusion that the motto of these and companion volumes of the medical history of World War II could well be "He who does not read history is often obliged to repeat it."

MORRIS C. LEIKIND
Armed Forces Institute of Pathology

Quest for a Continent. Walter Sullivan. McGraw-Hill, New York, 1957. 372 pp. Plates. $5.50.

Operation Deepfreeze. George J. Dufek. Harcourt, Brace, New York, 1957. 243 pp. Illus. + plates. $5.

Antarctica, earth's last stronghold to resist the encroachments of man, is about to be opened up. To those wishing to be brought up to date on its history and the problems which it poses to the scientists of the International Geophysical Year, these books are strongly commended.

Quest for a Continent is an intelligent man's guide to the antarctic, with particular emphasis on the part played by the United States in its exploration and scientific exploitation. As special correspondent of the *New York Times* on three antarctic expeditions, Walter Sullivan is well qualified to handle his brief; bristling as the subject does with historical controversy, political acrimony, and scientific complexity, the author is to be congratulated on presenting the general reader with an account that is well-informed, free from bias, and entirely readable.

Histories of antarctic exploration there are in abundance; Sullivan has wisely not labored to detail the exploits of early explorers but has highlighted postwar developments in antarctic exploration and research. His chapters on the United States Navy's Operation Highjump and Operation Deepfreeze gain added interest from the fact that he was an eyewitness on both occasions. How forcibly his narrative brings home the revolution that has taken place in polar exploration! The "heroic era," with its privately backed amateurs "muddling through" with dog team and sledge, living on the brink of subsistence, is past. The technical achievements of World War II ushered in a new "scientific era" of government-sponsored expeditions, lavishly equipped with huge icebreakers, long-range aircraft, helicopters, tracked vehicles of all kinds, and living accommodations with all the amenities of civilized life. Against these highly mechanized operations, it has been facetiously remarked, "the antarctic never stood a chance"—an unjustifiable quip, since, as these chapters so vividly show, exploring a continent in the grip of an ice age still presents formidable obstacles.

The scientific and economic significance of the "Last Continent" are outlined in the opening and concluding chapters of the narrative. How did Antarctica come into being? Was the geologic nexus known as Gondwana land, of which it is supposedly a part, a single continent which broke up and drifted apart, or did parts of it subside, leaving oceans in its place? Is the present northern glacial recession being reflected in the south? It has long been assumed that this is the case, but in fact the evidence is conflicting. Were this to be confirmed, the implications would be far-reaching. Only a slight modification in climate would be sufficient to make accessible the hidden mineral resources now buried under the ice. How much ice is at present locked up in the antarctic and to what extent might its melting be expected to affect the level of the oceans? These are but some of the problems to which scientists will devote themselves during the next 18 months.

After Sullivan's introduction to Operation Deepfreeze, an account of the United States Navy's most ambitious antarctic expedition, it is additionally rewarding to read the more detailed story of this enterprise (*Operation Deepfreeze*) as related by the commander of the task force himself. Rear Admiral George Dufek, disciplined in the school of the late Admiral R. E. Byrd and a veteran of two arctic and two antarctic expeditions, enjoyed the unique privilege of being elevated to the rank of rear admiral while he was on the retired list, by a special act of Congress, in order that he

might carry out active duty in that status. His assignment was a formidable one—namely, the establishment of land stations on the antarctic continent for realization of the objectives of the United States scientific program during the International Geophysical Year.

During the first phase, 1955–56, in which 1800 men took part, the main bases at Kainan Bay (Little America V) and McMurdo Sound were established—the latter an airstrip to which long-range aircraft were flown in direct from New Zealand and from which carefully planned, overlapping flights over the interior of the continent were made. In the second phase, 1956–57, in which 3400 men were employed, Byrd Station, IGY South Pole Station, Wilkes Station on the Knox Coast, and Ellsworth Station on the Weddell Sea were completed.

Constructing the South Pole Station proved to be the toughest assignment of all. Many tons of equipment had to be transported there by air, 780 miles to the south of McMurdo Sound. No aircraft had ever landed on the polar plateau, 10,000 feet above sea level. Dufek himself accompanied the ski-equipped sky train, which touched down at the pole on 31 Oct. 1956. He and his companions were the first Americans to set foot there, and the first human beings to experience its searing winds since Amundsen and Scott, 44 years previously. With the skis frozen to the ground by the intense cold (−58°F) the take-off proved to be a hair-raising experience; all 15 jato bottles were blown off before the planes finally lurched into the air. The author relates this and other adventures with fine understatement.

The text is accompanied by a welcome list of IGY stations in Antarctica and of their locations, by plans of the United States bases, and by a useful bibliography.

H. G. R. King

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Natural History of Birds. A guide to ornithology. Leonard W. Wing. Ronald Press, New York, 1956. 539 pp. Illus. $6.75.

Ornithological treatises, encyclopedic in scope, have long been available in German and French but have necessarily remained closed books to the monoglot American reader. Leonard Wing's handsome *Natural History of Birds* thus represents a truly valuable addition to the zoological shelf.

"This book was written for people interested in birds wherever found or studied—whether in classroom, laboratory, library, garden, woods, or field. It was planned as a general reference and as a bird book to accompany a field book or field guide. It considers the bird always as a living thing—one that lives a free and natural life. In a sense, it is a study of comparative bird biology focused on the life of the bird as a living thing." So states the author in his preface, and I can attest to the high degree of success that he achieves with this as his goal. As a museum worker, I am frequently asked, by press and public, to give factual answers to recurrent questions, and I am astonished at the number of such answers, derived from the most recent investigations in field and laboratory, that are made readily available in this book.

In 24 chapters, each followed by a list of "suggested reading," Wing deals with almost every conceivable aspect of ornithology, ranging from classification, through anatomy, physiology, evolution, ecology, and ethology, to economic relations with man. His text is everywhere enriched with photographs, figures, tables, and charts, and four appendixes are devoted to bibliographic references (19 pages), a synoptic classification of the birds of the world, a list of the official state birds, and a comprehensive glossary (13 pages). The book closes with an extensive index.

In reviewing a work of such range as this, any critic worthy of his review copy should find it easy to devote one or more paragraphs to censure. I am therefore almost embarrassed by my failure to detect any gross errors in the author's presentation; I have, indeed, noted only two minor lapses, in the spelling of scientific names ("*phoeniceous*" on page 145 and "*hypobellus*" on page 160). I highly recommend this volume.

H. G. Deignan

Smithsonian Institution

Family Medical Costs and Voluntary Health Insurance: a Nationwide Survey. Odin W. Anderson with Jacob J. Feldman. Blakiston Div., McGraw-Hill, New York, 1956. 251 pp. Illus. $6.50.

This book is not, as is stated in the nice foreword by Franklin D. Murphy, "the only comprehensive study since . . . 1933," but it is a sound and timely study of medical costs and the extent to which they are met by insurance. The study was based on sampling methods, and the work was quite obviously done in a competent manner by people proficient in these techniques. Although it is always hazardous to project to millions of families the conclusions reached from a study of a sample of only 2809 families comprising 8846 individuals,

the authors seem to have great confidence in the validity of the projection, and at this moment there are certainly no better figures available.

The need of such figures was felt by the President's Commission on the Health Needs of the Nation when it investigated this same field, and the results will be widely utilized and quoted by workers in this field. Nothing which was very startling was uncovered in this study, but the tremendous extent of prepayment and insurance in meeting medical costs (more than 100 million people have some coverage) will surprise some people. A follow-up to show trends will be valuable, for the scene changes rapidly. The statistical tables are very worth while, because they are current and provide at this time perhaps the only answers to many questions which are constantly arising.

This book will increase the already considerable stature of the authors. It is to be hoped that it will be followed by more work of a similar nature. The correlation with other surveys currently being conducted and with the U.S. Public Health Service surveys will be interesting. It is another important addition to a growing literature in this important field of the socio-economical aspects of medical care.

RUSSEL V. LEE

Palo Alto Medical Clinic

1001 Questions Answered about the Seashore. N. J. Berrill and Jacquelyn Berrill. Dodd, Mead, New York, 1957. xii + 305 pp. Illus. $5.

A distinguished marine zoologist and his wife have written this book of questions and answers for the casual explorer of the seashore who likes to poke in beach drift, search the tidepools, and dig in the sand; for adults and children who are curious to know more (but not too much more) about the things they see.

The book is not another aid for identification; the reader is referred elsewhere for this. Organisms are given generic, group, or local common names, and the information presented often applies broadly to a group or to several species. This seems to be a happy choice. Names are useful things, but they contain such satisfying magic that we are often deluded into thinking that to label something properly is to know all about it. "That is *Arbacia,* a sea urchin," we say and tramp on, satisfied that we have dealt with the beast appropriately and now understand its niche in the cosmos. The present volume is a pleasant antidote for this affliction. Its prime concern is natural history lore; where organisms live, how they reproduce themselves, what and how they eat, and their ways of protecting themselves from adverse conditions and enemies; it deals with form, color, size, and life-spans, with how organisms move, breathe, see, attach themselves, and heal damaged parts.

The questions (1106, not 1001) vary from trivial to complex, the answers from brief sentences (or cross references) to three-page discussions. Biologists who have visited the shore with children and friends will find the questions familiar, and the answers perhaps similar to their own replies. Information is thus neatly packaged and seems very well selected and presented for its intended readership. The advanced student and specialist will find some answers unsatisfyingly incomplete and some which apply only to certain species or regions (particularly the eastern American coast) or which could stand further qualification; on the other hand, it is a rare professional who would not learn something from this book. Errors of fact are few and as inconsequential as they are inevitable in a work of this scope.

The more conspicuous animals (mollusks, echinoderms, crustaceans, and so forth) are emphasized, but lesser groups are not omitted. The table of contents lists some groups (tusk shells, sea spiders, and insects) which are given brief mention and omits others (crabs, starfishes, and so forth) dealt with at much greater length. However, the 20-page index, the cross-referencing of questions in the text, and the arrangement of animals by systematic groups, make it easy to locate desired information. The 166 line drawings and 30 photographs help make this an attractive book as well as a very useful addition to the seashore library.

D. P. ABBOTT

Hopkins Marine Station,
Stanford University

Nuclear Weapons and Foreign Policy. Henry A. Kissinger. Published for the Council on Foreign Relations by Harper, New York, 1957. xx + 455 pp. $5.

This book has some large merits and also some quite striking defects. In view of the competition, it does not sufficiently compliment this book to say that it is clearly the best that has thus far appeared in the field of United States national security policy —one is tempted to say "in the field indicated by its title," but the title is inappropriate, since the book has little to say about foreign policy generally.

Perhaps our praise belongs really to the several outstanding articles by the same author which were the precursors of the present book, for they had a novelty which the book is bound to lack. In

the first and best of these articles, which appeared in the April 1955 issue of *Foreign Affairs*, Henry Kissinger valiantly explored the possibilities of providing sensible alternatives (that is, limited war) to the then dominant idea of "massive retaliation," especially with respect to defending the so-called "gray areas" outside Europe. He was not alone in such efforts, as he knew, but his thinking was nevertheless marked by strength and independence. It is now useful to have his distinctive point of view available to the public in book form.

The chief defect of the book is that it is not scholarly. For a book to be scholarly means, among other things, that the author must be modest and cautious, which this author decidedly is not. From beginning to end of this long book, Kissinger seems never to consider the possibility that his view on the particular issue under discussion may be wrong, and that it is certainly untested—or that his information may be too limited or the problem too big to justify his having a decided view at all. The factual errors that I noticed are few, and they would be easily forgiven if it were not for the tone of omniscience that breathes through the book.

It is also remarkable that the author never finds it necessary to acknowledge indebtedness for any of his ideas—or at least concurrent or even prior publication of similar views, however independently his own were derived. In the few places where his footnotes refer to the source of an idea as distinct from a fact, it is invariably because he disagrees with the idea in question. Surely he did not intend that his general bibliography should carry the moral burden he seems to thrust upon it, but if he did, there are some striking omissions. It is true that political science generally has become lax in these matters, but Kissinger's laxity is exceptional even for political scientists.

It is also unfortunate that the book does not include an index.

BERNARD BRODIE

Rand Corporation

Archaeology in the U.S.S.R. Mikhail Miller. No. 3 of *Research Monographs* of the Research Program of the U.S.S.R. Praeger, New York, 1956. 232 pp. $5.

Archaeology in the U.S.S.R. is a history of archeological research in European Russia which embraces all periods, from the very beginning in the 18th century to the year 1953. It is an English translation from the Russian, originally published in 1954 in Munich. The author, a Ukrainian professional archeologist from Rostov-on-Don, now living in Germany, is one of the rare witnesses of the inside story of archeology in Russia. He took part in the development of Russian archeology for more than 50 years, until World War II, and knew personally the majority of Russian and Ukrainian archeologists. He was a part of the older generation. The information regarding postwar developments is based on published sources, and hence the author does not picture the postwar situation as fully and reliably as he does that of the 1920's and 1930's. This book has been written primarily from the author's personal recollections and impressions.

Since the years 1930–34, archeological studies in the U.S.S.R. have fallen into the hands of the all-controlling Communist Party. The traditional forms of research in existence during the 19th and at the beginning of the 20th century were stopped; the well-educated generation of archeologists was liquidated. A new archeology had to be created by the "new" people, who could and had to understand the demands of the Marxist approach to science. Archeologists had to worship the doctrine of Marxism and the theory established by a philologist, Marr, who at that time was the president of the State Academy for the History of the Material Culture. All knowledge of prehistory was based merely on social-economic theses. The classification of the history of mankind was built on the evidence of social structures, regardless of the fact that archeology cannot tell much about the social structure of the remote periods of prehistory. After 1950–51 the name of Marr was replaced by that of Stalin. The battle with the ideas expressed in the literature of Western countries, particularly of the United States, reached its culmination.

Mikhail Miller has shown very clearly how archeological studies in the U.S.S..R were inseparable from the general domestic and foreign policy of the Soviet empire; how they pulsated in the same rhythm; how they changed their colors regardless of scientific logic, regardless of truth. The Soviet archeologists ignored the necessity of collaborating with the scholars of the Western world and developed a separatist research program. The book pictures the history of an archeology which was continually forced to forget its essential aims, to desert its devoted servants, and to float on an unstable basis for many years. The enumeration of the names of the martyrs for archeology will remain an eloquent document in the general historical research in archeology.

The detailed examination of the prevailing spirit in every period furnishes us with evidence for the understanding of the specific character of Soviet archeological literature, which is so different from that of the Western Hemisphere. In addition to

analyzing these fatal disasters dominating Soviet science, Miller tries to show objectively the positive results in archeological research. A considerable amount of excavation work, sponsored by the state, was carried on, and the value of this factual material will never diminish.

This book gives Western scholars an excellent idea of what has happened to anthropological and historical research in the U.S.S.R. The related story will undoubtedly lead the Western scholars to a greater appreciation of the free thought which they enjoy.

MARIJA GIMBUTAS

Harvard University

Light, Vegetation and Chlorophyll. J. Terrien, G. Truffaut, and J. Carles. Translated by Madge E. Thompson. Philosophical Library, New York, 1957. 288 pp. Illus. $6.

This little book is an elementary discussion and summary of our knowledge of photosynthesis. It brings matters down to perhaps 1952 and, consequently, does not include recent information. It contains, nevertheless, some useful chapters. The authors start with a consideration of the nature of light, the absorption of sunlight by the atmosphere of the earth, and the earth's energy balance. This is followed by discussion of the optical properties of leaves and of the behavior of leaves and plants in infrared and ultraviolet. These chapters are useful in that they contain a fair amount of information with which biologists in general are not familiar. The authors then go on to characterize photosynthesis as a process—effects of light intensity, CO_2 pressure, temperature, action spectra, and so on, concluding with a very brief discussion of the quantum efficiency of photosynthesis, which they end by provisionally accepting a yield of one O_2 molecule per 4 quanta absorbed and remark that "it remains to be seen in the future whether the few experiments which contradict this result are confirmed or not."

Little is said about the nature of the initial photochemical act, although a chapter is included on the photographic process, in which it is suggested that this may serve as a model of the photochemical end of photosynthesis. Phototropism, photoperiodism, the chemistry of chlorophyll, and the path of carbon are discussed briefly and in elementary fashion.

A final chapter takes up photosynthesis as a resource. The authors suggest that plant energy (that captured by the plant) is grossly undervalued, since it appears that in France human energy is at least 100 times more expensive. They wish also to banish the "neo-Malthusian's bugbear of overpopulation," pointing out that much more food can be grown in the world than is presently grown merely by spreading our agricultural technology and intensive agriculture to all corners of the world, which of course is true. And an interesting little analysis considers the return, in calories, from the use of water for the growing of plants as contrasted with the use of water for the turning of a turbine and generation of electricity. It turns out that water used for growing a plant and thus enabling it to capture solar energy returns about 100 times as much energy in usable form as does use of the same water to generate electricity on the basis of a 100-meter fall.

The translation leaves a flavor of the original French and is generally clear. Exceptions are the use of terms such as *glucoside* for sugar, *diastase* for enzyme, *tricarbonate* for 3-carbon compound.

There is a real place for a summary of light and vegetation—a summary of our knowledge of the energy balance of plants and of the photosynthesis of plants in assemblies. The present book, although it is a start along such a direction, does not fill the need. It does, however, possess the distinction that it may well be the only book on photosynthesis of recent years in which neither ribulose diphosphate nor the name of Melvin Calvin is to be found.

JAMES BONNER

California Institute of Technology

The Fight for Fluoridation. Donald R. McNeil. Oxford University Press, New York, 1957. 241 pp. $5.

As the title implies, this book is not intended to be a source of information concerning the scientific basis for fluoridation or its implementation by the water-works industry. For that type of information concerning fluoridation, the reader should consult publications such as *Fluoridation as a Public Health Measure* [American Association for the Advancement of Science (1954)]. In *The Fight for Fluoridation* there is presented a chronological account of the development of fluoridation as a public health measure, from the painstaking and devoted work of McKay and Black on endemic fluorosis, or mottled enamel, in Colorado Springs, Colorado, beginning in 1908, to the year 1957, at which time one may note that 1426 American communities, serving more than 30 million people and among which are included more than half of our major cities, are practicing fluoridation. It is a story of brilliant research, of grateful and enthusiastic re-

ception by a major segment of the American population, and of emphatic rejection by another.

It is to be hoped that the manner in which fluoridation has been received by a substantial segment of the American public does not reflect the real attitude toward men of science. Probably it does not, since one recalls that controversies over public health measures are not new but have produced some of the most bitterly fought campaigns in American history. This was true of the licensing of American medical practitioners, of vaccination, of immunization, and of the disinfection of public water supplies with chlorine. Now—as then—consumers of water supplies in cities large and small have been bombarded by claims and counterclaims which have often reached the fantastic. Opponents have denounced fluoridation as a potential killer, a violation of individual rights, the first step toward socialized medicine, and even as an attempt by Communists to mass-poison the population.

This is, on the whole, a story well told. Because it is a continuing one, the author appropriately closes his book with an eight-page chapter on contemporary sources of information available to those who wish to pursue the subject further. There is also a bibliography of almost 400 references to original source material, most of them accompanied by the comments of the author.

This is probably as accurate as any account can be when the feelings and emotions of human beings are involved. One outstanding error of interpretation should be noted. On page 82 the statement is made that water-works engineers became one of the first national organizations to approve fluoridation, that following this approval a storm of disapproval split their ranks, and that the American Water Works Association withdrew from its advanced stand and assumed a more neutral position. The statement is in error. The association does appear, in fact, in 1949 to have been the first national organization to adopt a policy with respect to fluoridation. This policy, however, was not one of approval. Its wording was as follows: "In communities where a strong public demand has developed and the procedure has the full approval of the local medical and dental societies, the local and state health authorities and others responsible for the communal health, water departments or companies may properly participate in a program of fluoridation of public water supplies."

In May 1951 the board of directors of the association reviewed its position concerning fluoridation of public water supplies, reaffirmed the 1949 statement, and added the following: "Recommendations for fluoridation are the prerogatives of the dental, medical and public health groups. When the proper authorities approve the treatment, it then becomes the function of the water works utility and industry to follow through willingly and intelligently where proper controls are assured."

The reader of this interesting book will find himself amazed, amused, chagrined, and proud of the varied reactions of an aroused populace to what is unquestionably one of the great advances in public health, not only of this generation but of this century.

A. P. Black

University of Florida

Follow the Whale. Ivan T. Sanderson. Little, Brown, Boston, 1956. xxiii + 423 pp. Illus. $6.

This is an irresponsible book, chattily but poorly written. My unfriendly estimate could be expanded and documented in the detailed manner of R. W. Hayman [*Nature* **177**, 445 (1956)] discussing another book by the same author. Ivan Sanderson's carelessness is evident, not only in his talk of whales and whaling, but also in his ordinary English, in his misused nautical and whalers' terms, and in his literary and historical allusions. This is the more regrettable, since, in general, he writes entertainingly and used to draw charming illustrations. Insofar as we serious scientists cannot write entertainingly for the public, we default in favor of less serious (less responsible) people who can.

I claim no great stature as a cetologist, but I have spent a good deal of time studying live whales in the water and dead ones in the laboratory, and it is hard for me to believe that Sanderson has had much experience with these animals. If a man is merely a writer, not also a doer, he needs much reading, at least. It is unfortunate that Sanderson did not profit by his own considerable bibliography (pages 379–405).

Without going into as great detail as Hayman, I submit a very sketchy sampling of my incomplete list of more than 40 arresting statements culled from the book. They concern biology, geography, misuse of professional and technical terms, and history; the frequent misspelling of technical names of animals is not detailed here.

On page 365, speaking of *Inia* and its flippers, the author says, "it uses them to cross mudbanks, like a sea lion galumphing over a beach, raising its forequarters off the ground when completely out of water." (I have handled live *Inia* in and out of water—where it is as helpless as any other cetacean—and find it extraordinarily difficult to detect a trace of truth in this amazing statement; no possi-

ble movements of a stranded porpoise could simulate a "galumphing" sea lion.) On page 191, speaking of *Tursiops*, he says, "they will eat up to a hundred pounds in a day"; this is a four- to five-fold exaggeration, even for captives. On page 378 (see also page 210) he summarizes his extravagant refinement of the "semirotary" swimming theory—as always, without evidence; although Sanderson is by no means the first enthusiast for this idea, he has removed it even further from the realm of anatomical and hydrodynamical possibility. On page 207 he shows that he too can be confused by diving physiology, and on this same page he rather overstates the asymmetry of owls. Careless geography shows not only in his maps but also in his making Williamsburg, Virginia, a seaport (page 213) and in his putting Botany Bay in Queensland (page 230). "Breaching" is repeatedly (for example, pages 66, 99, 339) misused for "surfacing to blow"; a spectacular failure to understand what he is saying occurs on page 290, where a ship goes through a wave, "splicing it apart," leaving it, we suppose, separately connected. There is incredible nautical nonsense on this and the preceding two pages, as also on many others.

Unsupported philology is scattered throughout the book, giving a spurious air of scholarship. And on page 94 Sanderson thus dismisses the highly competent navigator, Amerigo Vespucci: "a rather paltry late-comer from the Mediterranean who either only sailed up the Mississippi or never reached the northern continent at all." And the man who wrote that gibes at Pliny!

WILLIAM E. SCHEVILL
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Woods Hole Oceanographic Institution

The Language of Modern Physics. An introduction to the philosophy of science. Ernest H. Hutten. Allen & Unwin, London; Macmillan, New York, 1956. 278 pp. $3.75.

Ernest Hutten subtitles his work "An introduction to the philosophy of science." Its six chapters divide naturally into three parts. The first two chapters deal with logic and semantics; the next three consider the basic concepts of classical and modern physics; and the last chapter discusses general characteristics of the scientific method. The book is addressed to the layman and is therefore kept on a nontechnical level. There are, for instance, scarcely a dozen formulas of logic or physics in the whole volume. Yet Hutten has written a serious work which he hopes will be read by both philosophers and physicists. I am prepared to recommend Hutten's book as being definitely superior to most of the similarly oriented books written by such English scientists as Eddington, Whittaker, or Hoyle. At no point is the book marred by a naive epistemology or by vague cosmological speculations—the besetting sins of many books on physics addressed to the layman.

There are, however, some general criticisms that I would like to make. The first is that the attempt to relate semantics to physics seems somewhat pretentious and premature. Any detailed application of semantics requires a formalized language, but, as the author repeatedly remarks, no such languages have yet been constructed for any substantial portion of physics. As a consequence the author's insistence on the relevance of semantics to physics leads to yet another nearly empty programmatic proposal in the philosophy of science. The author does not indicate a single clear *result* that might be obtained by such an application of semantics. In fact, once he turns to the analysis of particular physical concepts, the author's use of semantical notions is fairly superficial. A typical instance is his use of *model* in the vague sense of physics rather than in the precise and important sense of semantics.

What is surprising, in view of the author's interest in formalizing physics, is his neglect of the research which has been done on axiomatizing various theoretical portions of physics; only Carathéodory is mentioned. The author does not mention the work of Hamel, Hermes, Robb, Schnell, A. G. Walker, and others. Axiomatization of physical theory, as opposed to experimental work, may proceed in the standard mathematical manner within a set-theoretical framework and without recourse to semantics. The more modest aim of first axiomatizing theoretical physics in the sense just defined, which is the sense in which mathematicians axiomatize topology or the theory of Hilbert spaces, would seem to be a necessary prolegomena to any applications of semantics to the full corpus of physics, theoretical and experimental.

Following Carnap and other writers, the author distinguishes two kinds of probability: inductive probability or degree of confirmation, and probability as the limit of relative frequency. Concerning Hutten's generally sound discussion, I have two comments. One is that the reader is not made sufficiently aware of the severe difficulties which must be overcome by any adequate theory of inductive probability. And the second is that it is contrary to scientific practice to speak of the inductive probability of *sentences* on given evidence. This linguistic approach of philosophers unduly and unnecessarily isolates their work on the foundations

of probability from the mainstream of probability theory. The problems and results of inductive probability may all be formulated in the ordinary sample-space framework. Moreover, such a formulation emphasizes the fact that the fundamental problems of induction are problems of action or decision and not problems of language.

PATRICK SUPPES

Stanford University

A History of Mechanics. René Dugas. Translated by J. R. Maddox. Griffon, Neuchâtel, Switzerland; Central Book Company, New York, 1955. 671 pp. Illus. $15.

This important book first appeared in French in 1950 and won immediate and deserved praise for its heroic achievement. It contains a summary of all the important contributions to mathematical mechanics, from ancient Greece to 20th-century relativity and quantum theory. More than this, it avoids the most common pitfall of previous comprehensive treatments of this central part of the history of science by including an ample discussion of medieval and early Renaissance sources, so that developments in the ages of Galileo and Newton do not appear to arise magically from nowhere.

For the completeness of the presentation at the early end of the time scale, we must thank the tradition of Duhem, Mach, and Jouguet, on which René Dugas leans heavily. For the more modern period he has had to rely on his own resources alone, and he earns our admiration and respect for a very clear-sighted exposition of the powerful analytic methods devised during the last century. One might well quarrel with details of choice—I should have liked to see more prominence for the school of mathematical physicists represented by Maxwell and Tait, by Kelvin and Rayleigh, and by Willard Gibbs and less for that of Navier or for the relativity and quantum theories, which receive such extensive treatment. But, in the main, this is one of the most complete and detailed accounts available in one volume for any part of the history of science or mathematics.

Although this is an indispensable work of reference and a good job well done, it is not history. It no more constitutes a history of mechanics than a chronological list of battles constitutes a military history. The author writes, indeed, as if mechanics had no history, only a sort of logical or sequential development, theory by theory. Names and dates appear almost as irrelevancies, contributing nothing to the main theme of evolution of the theory. This is not necessarily a disqualification; it is a valuable counterpoise to that other class of treatment that deals with the history and personalities of scientists almost to the exclusion of any consideration of the content and theory of their works. This is why the history of science must constitute a field in its own right; writings by plain scientists or by plain historians must inevitably lack completeness.

A more serious fault, though a very unusual one, is that Dugas has relied too much on original sources alone. In scientific work it is only commendable to pass by the secondhand opinion of others and discover the truth *ab initio*. It is not, however, always thus in historical criticism, and a self-made man in this art is likely to show all the shortcomings of unskilled labor. The author would have done well to make himself more familiar with the professional literature of historians of science since Duhem; much has been achieved in the last 40 years. A short appended note in this edition, mentioning some of the more recent literature, does little to remove a basic fault of this book.

It is also a great pity that Dugas has been badly served by the barely passable and very stilted translation and by faulty proofreading, although the diagrams and the printing are in general of the highest standard. It says a great deal for the author that, in spite of these faults and limitations, this English edition will be welcomed as a landmark in writings on mechanics and that it will be a long time before it can be bettered or can be displaced from our shelves.

DEREK J. PRICE

Smithsonian Institution

About Earthquakes. George A. Eiby. Harper, New York, 1957. 168 pp. $3.

In *About Earthquakes,* George Eiby tries to answer the kind of questions which he is frequently asked by visitors to the seismological station at the Dominion Observatory in Wellington, New Zealand. A chapter on observed earthquake intensity is followed by one on recording of earthquakes by instruments; this includes a description of the main types of seismographs, with good illustrations. In Chapter 3, "Reading the records," Eiby introduces the main types of waves and their paths through the earth's interior, with 14 seismograms corresponding to selected distances. In Chapter 4, "The first by-product," he summarizes, in seven pages, the use of elastic waves in finding the structure of the earth's crust and in seismic exploration. This is followed by chapters giving some geologic background and findings concerning the structure of the earth's crust and its interior.

"How earthquakes happen" is illustrated by good pictures of effects of recent faulting and includes fundamental ideas about isostasy, creep, the direction of initial ground motion, and trigger forces. "Where earthquakes happen" contains world maps of large shocks; here the problem of deep-focus earthquakes is introduced. Chapters on volcanic earthquakes (five pages) and on microseisms and tsunamis (six pages) are followed by one on earthquake engineering (nine pages). "Some famous earthquakes" conclude the text.

An appendix includes facts and figures about the earth, the modified Mercalli scale of intensity, and lists of historical earthquakes from 1500 to 1904, and of important earthquakes since 1904. On the last four pages Eiby gives data on major earthquakes in New Zealand and a short list of books and journals.

The book fills the need for an up-to-date elementary introduction to selected fundamental ideas about earthquakes and the structure of the earth; it can be highly recommended for this purpose. There are only a few minor errors in the text. The printing is good, and most of the 32 plates are excellent, but the reproduction in many of the 54 figures, especially the reproduction of seismograms, could be improved; frequently the lettering is too small. The title of the British edition of the book is *Earthquakes.*

BENO GUTENBERG
California Institute of Technology

The Amateur Astronomer. Patrick Moore. Norton, New York, 1957. xiv + 337 pp. Illus. + plates. $4.50.

A Key to the Stars. R. van der Riet Woolley. Philosophical Library, New York, ed. 3, 1957. 141 pp. Illus. + plates. $4.75.

Although astronomers are few in number, compared with professionals in the other physical sciences, the subject of astronomy nevertheless has wide popular appeal among numerous amateur astronomers and others interested in science. Consequently, it offers a relatively large market for books on an elementary level. These two books are intended for that general market but are designed for slightly different audiences.

Patrick Moore has had experience both as an amateur astronomer himself and as a coworker with other amateurs in his capacity as director of the Mercury and Venus section of the British Astronomical Association. His book is written primarily for the beginning amateur astronomer who knows very little about the subject and desires a description of the various celestial bodies and their motions and gives him some suggestions about how to use his telescope to the best advantage. In accordance with the interest of most amateurs, the greater part of the discussion is devoted to objects in the solar system.

The style is pleasant and light, with the more serious discussion occasionally interspersed with anecdotes and facetious jibes. As a handbook for beginning amateurs, I recommend it; but the book is a little disappointing insofar as summaries of modern theories and descriptions of recent advances (that have not yet found their way into textbooks) are concerned.

Perhaps the most valuable feature of the book, and one that should appeal to many amateur astronomers, is the group of 29 appendixes, comprising nearly 100 pages and including a large variety of data on planets, as well as lunar maps, star maps, Messier's catalog, and many other useful tables.

The book by R. van der Riet Woolley (now the British Astronomer Royal) is designed not so much for working amateurs as for interested and intelligent laymen who, in Woolley's words, "are willing to take a little trouble to think about the subject." Being short and concise, this book should appeal to the reader who has no telescope in his back yard but desires strictly an armchair exploration of space in the course of an evening or two. But very few alterations have been made since the original publication of the book some 20 years ago, because "the elementary steps in astronomy and astrophysics . . . have not really changed at all."

I disagree. Since the book presents astrophysical research in such a charming manner, the omission of any appreciable discussion of techniques applied to research since World War II is disappointing. For example, multicolor photoelectric photometry has provided knowledge on stars whose chemical composition is different from that in the solar atmosphere and has played a key role in our present idea of stellar evolution. Radio observations, a powerful new supplement to optical techniques, are breaking barriers in nearly all areas of astrophysics, from the aurora to colliding galaxies. Polarization studies have provided evidence of galactic magnetic fields which may play an important role in galactic structure and the origin of cosmic radiation. New observations of magnetic fields in the sun and in certain other stars, coupled with theoretical work in hydromagnetics, have helped revolutionize our ideas of the physics of "matter in the large."

There is no denying that much of the book is still quite up to date, or that Woolley has presented a lucid account of astrophysical spectroscopy and

other topics. But I think that the reader who is "willing to take a little trouble" would appreciate an account of astrophysics as a dynamic and progressing subject, utilizing new tools and ideas, as well as the old, to penetrate the mysteries of "things outside the earth."

JOSEPH W. CHAMBERLAIN
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Books Reviewed in SCIENCE

August 2

The Climate near the Ground, R. Geiger; translated by M. N. Stewart *et al.* (Harvard Univ. Press). Reviewed by H. E. Landsberg.

Botany, W. W. Robbins, T. E. Weier, C. R. Stocking (Wiley; Chapman & Hall). Reviewed by H. B. Creighton.

Physical Techniques in Biological Research, vol. II, *Physical Chemical Techniques*, G. Oster and A. W. Pollister, Eds. (Academic). Reviewed by H. Yagoda.

Technical Aspects of Sound, vol. II, *Ultrasonic Range, Underwater Accoustics*, E. G. Richardson (Elsevier; Van Nostrand). Reviewed by W. P. Mason.

Handbook of Snakes of the United States and Canada, vols. 1 and 2, A. H. Wright and A. A. Wright (Comstock; Cornell Univ. Press). Reviewed by R. Conant.

Handbuch der Physik, vol. XXX, *X-rays*, S. Flügge, Ed. (Springer). Reviewed by I. Fankuchen.

August 9

Selected Papers in Statistics and Probability by Abraham Wald, T. W. Anderson *et al.*, Eds. (Stanford Univ. Press). Reviewed by J. Neyman.

The Water Relations of Terrestrial Arthropods, E. B. Edney (Cambridge Univ. Press). Reviewed by E. H. Slifer.

Nonparametric Statistics for the Behavioral Sciences, S. Siegel (McGraw-Hill). Reviewed by S. Messick.

Advances in Cancer Research, vol. 4, J. P. Greenstein and A. Haddow, Eds. (Academic). Reviewed by M. B. Shimkin.

Separation and Purification, vol. III, pt. 1, of *Technique of Organic Chemistry*, A. Weissberger, Ed. (Interscience). Reviewed by K. L. Rinehart, Jr.

High Energy Accelerators, vol. I of *CERN Symposium on High Energy Accelerators and Pion Physics, Proceedings* (European Organization for Nuclear Research, Geneva). Reviewed by R. O. Haxby.

Early Electrical Machines, B. Dibner (Burndy Library). Reviewed by R. P. Multhauf.

Ernest Rutherford, Atom Pioneer, J. Rowland (Philosophical Library). Reviewed by R. T. Birge.

Progress in the Chemistry of Organic Natural Products, vol. 13, L. Zechmeister, Ed. (Springer). Reviewed by H. Feuer.

August 16

The Prospects of Nuclear Power and Technology, G. Wendt (Van Nostrand). Reviewed by H. Brown.

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Vapour Phase Chromatography, D. H. Desty, Ed. (Academic; Butterworths). Reviewed by F. L. Howard.

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Scientific Inference, H. Jeffreys (Cambridge Univ. Press). Reviewed by M. Scriven.

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A Symposium on the Chemical Basis of Heredity, W. D. McElroy and B. Glass, Eds. (Johns Hopkins Press). Reviewed by E. L. Tatum.

Professional Amateur, T. A. Boyd (Dutton). Reviewed by B. C. Hendricks.

August 23

Cytology and Cytogenetics, C. P. Swanson (Prentice-Hall). Reviewed by F. Schrader.

Molecules and Crystals in Inorganic Chemistry, A. E. Van Arkel (Interscience). Reviewed by J. Donohue.

Biogeography, P. Dansereau (Ronald). Reviewed by E. Anderson.

Modern Science and Human Values, E. W. Hall (Van Nostrand). Reviewed by E. Topitsch.

Analytical Pathology, R. C. Mellors, Ed. (McGraw-Hill). Reviewed by A. A. Liebow.

Route-Mapping and Position-Locating in Unexplored Regions, W. Filchner, E. Przybyllok, T. Hagen (Academic). Reviewed by J. A. O'Keefe.

Optics, V. Ronchi; translated and revised by E. Rosen (New York Univ. Press). Reviewed by A. E. Murray.

Lectures on Rock Magnetism, P. M. S. Blackett (Weizmann Science Press of Israel). Reviewed by J. R. Balsley.

Climate and Economic Development in the Tropics, D. H. K. Lee (Harper). Reviewed by C. A. Mills.

Some Principles of Energetics in Biochemical Reactions, I. M. Klotz (Academic). Reviewed by E. A. Evans, Jr.

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The American Oasis, E. Higbee (Knopf). Reviewed by P. B. Sears.

Methods of Biochemical Analysis, vol. 4, D. Glick, Ed. (Interscience). Reviewed by J. R. Gillette.

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The People of Puerto Rico, J. H. Steward, R. A. Manners, E. R. Wolf, E. P. Seda, S. W. Mintz, R. L. Scheele (Univ. of Illinois Press). Reviewed by C. Wagley.

Marine Algae of the Northeastern Coast of North America, W. R. Taylor (Univ. of Michigan Press). Reviewed by G. M. Smith.

Vergleichende Physiologie, vol. III, *Ernährung, Wasserhaushalt und Mineralhaushalt der Tiere*, W. von Buddenbrock (Birkhäuser, Basel). Reviewed by C. L. Prosser.

Matrix Calculus, E. Bodewig (North-Holland; Interscience). Reviewed by A. S. Householder.

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Nuclear Weapons and Foreign Policy. Henry A. Kissinger. Harper (for the Council on Foreign Relations), New York, 1957. 475 pp. $5.

The Hypercircle in Mathematical Physics. A method for the approximate solution of boundary value problems. J. L. Synge. Cambridge University Press, Cambridge, 1957 (order from Cambridge University Press, New York 22). 434 pp. $13.50.

Light Scattering by Small Particles. H. C. Van de Hulst. Wiley, New York; Chapman & Hall, London, 1957. 483 pp. $12.

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The Beginnings of Embryonic Development. A symposium organized by the Section on Zoological Sciences of the American Association for the Advancement of Science, cosponsored by the American Society of Zoologists and the Association of Southeastern Biologists, and presented at the Atlanta meeting, 27 Dec. 1955. Publ. No. 48. Albert Tyler, R. C. von Borstel, Charles B. Metz, Eds. American Association for the Advancement of Science, Washington, D.C., 1957. 409 pp. $8.75; $7.50 (members).

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Elements of Color in Professional Motion Pictures. Wilton R. Holm, Chair. Society of Motion Pictures and Television Engineers, New York, 1957. 104 pp.

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Industry and Technical Progress. Factors governing the speed of application of science. C. F. Carter and B. R. Williams. Oxford University Press, London, 1957. 252 pp. $4.

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The Measurement of Meaning. Charles E. Osgood, George J. Suci, Percy H. Tannenbaum. University of Illinois, Urbana, 1957. $7.50.

Mosses of Indiana. Winona H. Welch. Bookwalter, Indianapolis, Ind., 1957. 478 pp.

No Frontier to Learning. The Mexican student in the United States. Ralph L. Beals and Norman D. Humphrey. University of Minnesota Press, Minneapolis, 1957. 159 pp. $3.25.

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Synthetic Methods of Organic Chemistry, vol. 11. W. Theilheimer, Ed. Karger, Basel; Interscience, New York, 1957. 510 pp. $20.

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Lecture Notes on the Use of the Microscope. R. Barer. Thomas, Springfield, Ill., ed. 2, 1956. 76 pp. $1.50.

The Astonished Muse. Reuel Denney. University of Chicago Press, Chicago, Ill., 1957. 271 pp. $4.50.

(*Continued on page v*)

ASSOCIATION AFFAIRS

AAAS Indianapolis Meetings, 1871–1937

The 124th meeting of the American Association for the Advancement of Science this coming 26–30 Dec. is also the fourth Indianapolis meeting. The previous meetings in this key industrial center of the Midwest were held in 1871, 1899, and 1937. A brief comparison of the meetings not only indicates the growth of the AAAS—and of the societies that participate—but also provides an indication of the shifts in emphasis in scientific research. The development of the city and of the nation over 86 years is indicated, and the influence of the times and of the personalities of the past is reflected in the programs and proceedings of these earlier conventions. A number of members who attended the third Indianapolis meeting of 1937 will be in a position to make their own comparisons of the changes that 20 years have brought.

The first Indianapolis meeting, 16–22 Aug. 1871, was held relatively early in the long history of the association. It was only the 20th AAAS meeting, since there had been no meetings during the war between the North and the South. Before this there had been only one convention west of Ohio—the Chicago meeting of 1868.

When the proceedings of this meeting of 86 years ago are read, it is at once apparent that great changes in industry, in transportation, and in the growth of the nation, and at least equally great developments in science, have occurred. In 1871, the population of Indianapolis exclusive of suburbs, was 48,000—about one-tenth of what it is today. AAAS membership at that time was only 537; it has since increased 100-fold. For inland transportation, railroads were the only large carriers of freight and people. The railroads were relatively prosperous and in a phase of expansion. The use of steel rails and the spread of the Bessemer process of steel production were shortly to come. Then, as now, Indianapolis was a key center of the state and of the region. Indeed, every 24 hours, 80 trains

stopped at the Union Depot. In that halcyon period, when hospitality could be abundant and convention visitors could often send free telegrams, two of the 12 railroads that passed through the city invited the 196 AAAS registrants and their families to ride free on excursions to Terre Haute and to the Mammoth Cave in Kentucky. On the first of these trips, time was allotted for free refreshments at Knightsville and for a longer stop-off at Brazil, Ind., to inspect the coal and iron operations there and to partake of a bountiful dinner generously contributed by the townspeople. The city of Terre Haute entertained the delegates overnight, after a reception and addresses. At the close of the meeting, the citizens of Louisville and the Louisville and Nashville Railroad provided complimentary meals on the Mammoth Cave trip.

The technical sessions at which 107 papers were read before the then two sections—A–Mathematics, Physics, and Chemistry and B–Natural History (geology, zoology, botany, ethnology)—were held in the legislative chambers of the State House. The larger general sessions and social events were accommodated in the Academy of Music. General chairman of the first Indianapolis meeting was the Honorable Daniel Macauley, who headed a local committee of 95 members. At the committee's formal reception of the association, on the first afternoon, Governor Conrad Baker gave a brief address of welcome. This was responded to by retiring president Thomas Sterry Hunt, a prominent geologist and charter member of the Association, who had succeeded astronomer-mathematician William Chauvenet following the latter's death in office. A tribute was paid to the pioneer scientific work of William McClure and of the Owens, of Indiana's New Harmony community. Hunt's AAAS presidential address the same evening was a scholarly, historical review of the crystalline rocks of the Appalachians. Immediately afterward, Asa Gray, eminent botanist and also a charter member of the association, assumed the presidency of the first Indianapolis meeting.

In the last part of the 19th century, the emphasis in science was still on the descriptive, rather than on the experimental, aspects. Two of the longer papers, for instance, were "On the geological history of the Gulf of Mexico," by E. W. Hilgard (Oxford, Miss.), and "On the characteristics of primary groups of the class of mammals," by Theodore Gill (Washington, D.C.). Among the several resolutions passed at the business meetings were recommendations that the geologic survey of Missouri be published and that the Niagara Falls area be resurveyed.

After an interval of 19 years, the second Indianapolis meeting was held 19–26 Aug. 1890. As in 1871, sessions were held principally in the State House, which had been rebuilt. Nearby the Soldiers and Sailors Monument, a dominant feature of the center of the city, was in process of erection. Indianapolis had grown to be a city of 105,436 and now had 15 railroads; the membership of the AAAS had increased more than threefold, to 1944, and the number of sections had increased from two to eight.

Ten local committees, responsible for virtually all phases of the meeting, were headed by George W. Sloan, general chairman. Lieutenant Governor Ira J. Chase and Mayor Thomas L. Sullivan welcomed members of the association to the state and city. Social events were numerous and pleasant. At Woodruff Place one evening, General Lew Wallace, author of *Ben Hur*, addressed the visitors. An excursion was made to the natural-gas region of Indiana, the site of many diversified industries.

This 39th meeting to the association was under the presidency of Asa Gray's successor in botany at Harvard University, George Lincoln Goodale. The AAAS presidential address of retiring president T. C. Mendenhall, well-known physicist, on "The relations of men of science to the general public," would, in part at least, be not inappropriate for the present time. Mendenhall noted that AAAS meetings not only have served scientists but have brought them into closer relations with the public. He found, however, "that the relation between men of science and the general public is not what it should be in the best interest of either or both." Mendenhall said that the viewpoint of the layman "now and then [is] tinctured with contempt for men who devote their lives and energies to study and research, the results of which cannot always be converted into real estate or other forms of taxable property." Conversely, he pointed out that a number of scientists are unable or unwilling to present the results of their work to the intelligent public in understandable language; that men of science may assume superior wisdom on subjects outside their specialties; and that the interest of the scientist in public affairs should not be less than that of other men. Mendenhall observed: "It is generally recognized that, aside from all questions of a partisan political nature, this country is today confronted by several problems of the utmost importance to its welfare, to the proper solution of which the highest intellectual powers of the nation should be given."

There were 364 registrants from 30 states, the District of Columbia, and Canada and from several foreign countries at this meeting. Some 213 papers were read. Each of the eight sectional vice presi-

dents gave an address. The following list indicates the subjects of interest to each discipline at the time: A–Mathematics and Astronomy, Seth Carlo Chandler, "The variable stars"; B–Physics, Cleveland Abbe, "A plea for terrestrial physics"; C–Chemistry, Robert B. Warder, "Recent theories of geometrical isomerism"; D–Mechanical Science and Engineering, James E. Denton, "History of attempts to determine the relative value of lubricants by mechanical tests"; E–Geology and Geography, John C. Branner, "The relations of the state and national geological surveys to each other and to the geologists of the country"; F–Biology, Charles Sedgwick Minot, "On certain phenomena of growing old"; H–Anthropology, Frank Baker, "The ascent of man"; I–Economic Science and Statistics, J. Richards Dodge, "The standard of living in the United States."

This last address may be of considerable historical interest. In 1890, the American standard of living, Dodge found, was the highest known—with "no barriers to wealth or station which capacity and persistence cannot sweep away." Statistics were cited on the consumption of meat and other foodstuffs, which was conspicuously higher than elsewhere in the world. There was a parallel high consumption of wool and other textiles. Wages were 50 to 300 percent above those of any other country. Because of surpluses, prices for farm crops were not always satisfactory to the farmers. The question of whether such prosperity could continue was considered, and the speaker concluded that it could, provided that production commensurate with the rapidly growing population could be maintained.

Among the numerous items of business transacted, Section C lent its help to effect a consolidation of the 14-year-old American Chemical Society, then based in New York, with other groups of chemists to form an enlarged and truly national society. A resolution was passed by the council urging the U.S. Department of the Interior to take action to preserve tracts of sequoias in California. The council appropriated $250 from research funds to assist E. W. Morley and H. T. Eddy to continue their investigation of the velocity of light in the magnetic field.

The third Indianapolis meeting, 27 Dec.–1 Jan. 1937–38, was in marked contrast to the two previous meetings in that city. It was much larger and more complex. With some 30 societies holding their national meetings and with the sections of the AAAS by this time numbering 15, there were 3094 registrants, from every state except Nevada and Vermont, and the total attendance was estimated at 5000. A total of 1681 papers were given, in 225 technical sessions in 48 rooms and three laboratories, and the general program was 273 pages in length. AAAS membership had increased to 18,776, and the city's population was approaching 400,000.

In its general organization the 1937 meeting was typical of those of the present day, and it stands as 11th in size of all the 123 AAAS meetings to date. A substantial number of those who attended that meeting, and some who helped with it, will be present at this year's meeting, 20 years later. To mention but a few: Paul B. Sears, this year's retiring president of the association, read two papers, in botany and ecology; Thomas Park and Chauncey D. Leake, other current AAAS board members, read papers before the Ecological Society of America and Section L, respectively, and the latter also presided at a session as president of the History of Science Society. By a coincidence, Stuart A. Rice was vice president for Section K–Social and Economic Sciences—an office in which he is again serving at this year's meeting. A. W. Tucker, Isaac Schour, and Robert C. Anderson, current vice presidents for Sections A–Mathematics, Nd–Dentistry, and Np–Pharmacy, respectively, all read papers in 1937. Joseph J. Cripe, manager of the Indianapolis Convention Bureau, who served as chairman of the printing committee 20 years ago, has been an invaluable consultant this year and again is a member of local committees.

General chairman of the third Indianapolis meeting—the 101st meeting of the association—was Stanley Coulter; the Executive Committee was composed principally of the chairman of the eight special committees. The president of the AAAS was George D. Birkhoff, eminent professor of mathematics at Harvard University. The association's "permanent secretary" was F. R. Moulton, and the details of the meeting were the responsibility of Sam Woodley, F. C. Brown (exhibits), and Austin H. Clark (press service). As will be the case at this year's meeting, the AAAS main registration was at the Murat Temple, and the Claypool Hotel was AAAS headquarters. Other sessions were held in the same principal downtown hotels in which sessions are scheduled this year. In his report of this 1937 meeting, Moulton wrote: "It is quite possible that . . . [it] will be remembered as the beginning of a new era in the Association because of the increasing sense of responsibility of scientists to society. . . . The opinion was frequently expressed that in integrating the sciences—physical, biological, and social—and in examining the relations of all of them with society, the Association is rendering its greatest service to science and to the world."

The AAAS presidential address of the retiring president, Edwin G. Conklin (emeritus professor of biology of Princeton University), entitled "Science and ethics," was consistent with this emphasis. Conklin took issue with specialists who would maintain that science has no concern with ethics and made the point that any program for human welfare needs both areas of human thought. He observed: "Neither in human nature nor in social relations has progress kept pace with science. That is not the fault of science but rather of man and of society. The great advances in the applications of science have often been used for selfish purposes rather than for social welfare. . . . The fact is that social progress has moved so much slower than science that one might say that scientific progress is matched against social stagnation. Many thoughtful persons are asking: 'Will science, which has so largely made our modern civilization, end in destroying it?' " Conklin concluded that education in ethics and in human values is the chief hope of human progress and that men must live up to the best that they know. The AAAS presidential reception that followed was given by the local committee, with Mr. and Mrs. Eli Lilly at the head of the receiving line.

Among other highlights of the third Indianapolis meeting were the 16th Sigma Xi address, "Biological applications of surface chemistry," given by General Electric's Irving Langmuir, subsequently 94th president of the association, and the third Phi Beta Kappa address before the AAAS—"Shakespeare and the critics," by George Lyman Kittredge of Harvard University. This latter was preceded by a performance of Tschaikowsky's fourth symphony, by the Indianapolis Symphony Orchestra. A public lecture on "Syphilis as a public health problem" by Thomas Parran, Jr., Surgeon General, was the climax of a six-session symposium on the subject sponsored by Section N.

Among the many hundreds of short papers given at the 1937 meeting was one on the fine structure of television images and another that pointed out that automobile drivers under 25 years of age were responsible for 20 percent of the nearly 40,000 highway fatalities each year.

The Annual Exposition of Science, 13 years of age as an organized, integral part of AAAS meetings, had 69 exhibits, 34 of them commercial.

The 15th AAAS Newcomb Cleveland prize was awarded to Philip R. White for his paper "Root pressure: an unappreciated force in sap movement," read before the Botanical Society of America. The winner of the first Theobald Smith award, given annually by Eli Lilly and Company, was Robley D. Evans, then at Massachusetts Institute of Technology, for his studies of radium poisoning.

In summary, the records of the three previous meetings in Indianapolis succeed in conveying the warm spirit of hospitality and interest in the work of the association shown by the people of this great community of the Midwest.

RAYMOND L. TAYLOR
Associate Administrative Secretary

Election of AAAS Officers

The following candidates for the offices of president-elect and members of the Board of Directors have been selected by the AAAS Committee on Nominations on the basis of a preliminary balloting of AAAS Council members:

President-elect (one to be elected)
Paul E. Klopsteg
Chauncey D. Leake

Members of the Board of Directors (two to be elected)
Glenn L. Jenkins
Thomas Park
William W. Rubey
Maurice B. Visscher

Ballots for election by preferential mail vote will be sent to council members by 10 November. Election procedures established by the council provide that additional candidates for any of the elective offices may be nominated and included on the ballot by a petition signed by no fewer than 30 members of the council and submitted to the executive officer no later than 1 Nov. The results of the election will be announced on 27 Dec. at the Association's 1957 annual meeting in Indianapolis. Biographical data concerning each of the candidates follow.

Paul E. Klopsteg, 67 (physics), assistant in physics, University of Minnesota, 1911–13; instructor and later assistant professor, 1913–17; development engineer, Ordnance Department, U.S. Army, 1917–18; physicist, Leeds & Northrup Company, Philadelphia, 1918–21; director of research and manufacturing, Central Scientific Company, Chicago, 1921–30, president, 1930–44; professor of applied science, Northwestern University, director of research, Northwestern Technological Institute, 1944–54; assistant director for physical sciences, National Science Foundation, 1951, associate director since 1952, associate director for research, 1957–; deputy chief, instruments section, National Defense Research Committee, 1940–41, chief, physics (special devices) division, 1941–45; assistant chief, office field service, Office of Scientific Research and Development, 1944–45; chairman,

committee on artificial limbs (Prosthetics Research Board), National Research Council, 1945–56, member 1945–; member of the board of governors and chairman, Argonne National Laboratory, 1949–50; member, Personnel Security Review Board of AEC, 1953–; Modern Pioneers' award, National Association of Manufacturers, 1940; Presidential Medal for Merit, 1948; cofounder, American Association of Physics Teachers, 1930, president, 1953; member of the governing board, American Institute of Physics, 1930–45, chairman, 1938–45.

AAAS activities: member, Board of Directors, 1949– and Executive Committee, 1953–; member, Building Committee, 1952–54, and Investment and Finance Committee, 1950–54; chairman, Committee on Public Information and Science, 1957–.

Chauncey D. Leake, 61 (pharmacology, physiology, history of science, health administration), Chemical Warfare Service, instructor in physiology, assistant professor pharmacology, University of Wisconsin, 1919–28; professor of pharmacology and of history of medicine, lecturer on human relations, librarian, University of California Medical Center, San Francisco, 1928–42; director, professor of pharmacology and of history of medicine, University of Texas Medical Branch, Galveston, 1942–55; professor of pharmacology, assistant dean, Ohio State University, 1955–; special award International Anesthesia Research Society, 1928; president, History of Science Society, 1936–37; vice president, Society for Experimental Biology and Medicine, 1941–42; president-elect, American Society for Pharmacology and Experimental Therapeutics, 1957; chairman, Section on Pharmacology, American Medical Association, 1934; president, Honorary Consultants Army Medical Library, 1946–47; consultant, U.S. Department of Defense, U.S. Public Health Service, Veterans Administration; chairman, National Research Council Committee on Problems of Alcohol, 1947–54; founder and former editor of *University of California Publications in Pharmacology* and of *Texas Reports on Biology and Medicine*; associate editor *Isis, Journal of the History of Medicine, Excerpta Medica, Archives Internationales de Pharmacodynamie et de Therapie*, and *Geriatrics*; member, board of trustees, *Biological Abstracts*, 1956–; visiting member, Institute for Advanced Study, 1950, 1952, 1956; Logan Clendenning lecturer, University of Kansas, 1951; Wm. Snow Miller lecturer, University of Wisconsin, 1940, 1957; Josiah Trent lecturer, Duke University, 1956; Poynter lecturer, University of Nebraska, 1957.

AAAS activities: vice president and chairman of Section L, 1942, 1954; delegate to BAAS, 1953; member, Publications Committee, 1954–; member, Board of Directors, 1954–; chairman, Committee on Social Aspects of Science, 1957.

Glenn L. Jenkins, 59 (pharmacy, pharmaceutical chemistry), research fellow, 1922–24, instructor, 1924–27, University of Wisconsin; professor of pharmaceutical chemistry, University of Maryland, 1927–36, University of Minnesota, 1936–41; dean of the School of Pharmacy and professor of pharmaceutical chemistry, Purdue University, 1941–; American Pharmaceutical Association, Ebert medal for research, 1936; chairman, Section on Education and Legislation, 1929–30, chairman, Scientific Section, 1936–37, president, 1949–50, chairman, council 1940–41 and 1953–55; American Council on Pharmaceutical Education, 1948–54; American Association of Colleges of Pharmacy, president, 1944–46; National Formulary Revision Committee, 1930–47; U.S. Pharmacopoeia Revision Committee, 1940–; Indiana Interprofessional Health Council, 1941–, president, 1941–55; Indiana State Board of Health, 1944–; chairman, 1957; American Chemical Society, chairman, Purdue Section, 1949–50; associate editor, *Pharmaceutical Archives*, 1936–41; headed Pharmacy Mission to Japan, 1950.

AAAS activities: secretary, Section Np, 1938–55; vice president and chairman, Section Np, 1955–56.

Thomas Park, 48 (zoology, population ecology), National Research Council fellow, Johns Hopkins University, 1933–35; instructor in biology, Johns Hopkins University, 1935–36, associate, 1936–37; instructor in zoology, University of Chicago, 1937–39, assistant professor, 1939–42, associate professor, 1942–47, professor, 1947–, associate dean, Division of Biological Sciences, 1943–46; Rockefeller Foundation fellow, Oxford University, 1948; scientific attaché, American Embassy, London, 1949; Environmental Biology Panel, National Science Foundation, 1956–58; editor, *Ecology*, 1940–50; editor, *Physiological Zoology*, 1955–; editorial board, *Quarterly Review of Biology*, 1938–, *American Naturalist*, 1951–57; zoological adviser, *Encyclopaedia Britannica*, 1950–.

AAAS activities: member, Board of Directors, 1954–; chairman, Publications Committee, 1955–.

William W. Rubey, 58 (geology), instructor in geology, Yale University, 1922–24; successively geologic aid to principal geologist, 1920–44, geologist in charge, division of areal geology and basic sciences, 1944–47, research geologist since 1947, U.S. Geological Survey; chairman, division of geology and geography, 1943–46; general chairman, 1951–54, National Research Council; member, committee on geophysics and geography, Research and Development Board, 1947–50;

president, Geological Society of America, 1949–50; vice president, American Geological Institute, 1950–51; member, divisional committee on mathematics, physics, engineering, science, National Science Foundation, 1951–55; member, board of directors, Geochemical Society, 1955–; councillor, American Philosophical Society, 1956–; visiting professor of geology, Institute of Geophysics, University of California (Los Angeles), 1954, California Institute of Technology, 1955, Johns Hopkins University, 1956.

AAAS activities: member, Board of Directors (appointed to fill unexpired term), 1957; committee on Section E, 1939–42; committee on Newcomb Cleveland prize award, 1951; representative on board of directors, Science Service, 1956–.

Maurice B. Visscher, 56 (physiology), assistant, University of Minnesota, 1922–55; National Research Council fellow, University College, London, and University of Chicago, 1925–27; associate professor and professor of physiology, University of Tennessee, 1927–29; professor and head, department of physiology, University of Southern California, 1929–31; professor and head, department of physiology, University of Illinois, 1931–36; professor and head, department of physiology, University of Minnesota, 1936–; secretary, American Physiological Society, 1946–48, president, 1948–49, chairman, board of publications trustees, 1955–; board of directors, *Biological Abstracts*, president, 1949–53; board of directors, *Annual Reviews*; president, American Association of Scientific Workers, 1946–48; chapter president, American Association of University Professors, 1945–46; vice president, National Society for Medical Research, 1952–55; vice president, American Heart Association, 1950–51; president, Council of International Organizations of Medical Sciences, 1952–55; secretary general, International Union of Physiological Sciences, 1953–; member, National Academy of Sciences.

AAAS activities: council member, 1945–46; chairman, Special Committee on Civil Liberties, 1946–48.

AAAS Finances: Report for 1956

The financial records of the American Association for the Advancement of Science are kept in two separate accounts. One—the Current Fund (or operating account)—shows the expenses of running the Association's ordinary, continuing activities and the income that is devoted to those activities; the other—the Investment Account—includes funds that have been given to the association to endow prizes, to pay the cost of maintaining the membership of emeritus and life members, and to support research.

Current Fund

Operating receipts totaled $719,233.81 during 1956. They were divided as follows.

Annual dues paid by members	$306,003.52
Extra payments by members who wanted to receive both *Science* and *The Scientific Monthly*	22,237.15
Money transferred from the Investment Account to pay for subscriptions for emeritus and life members	3,568.50
Journal subscriptions from nonmembers	66,065.03
Sales of individual copies of journals	2,466.96
Advertising in *Science*	203,285.25
Advertising in *The Scientific Monthly*	11,598.03
Sale of symposium volumes	21,015.22
Miscellaneous sales, including journal binders, association emblems, and Microcard edition of *Science*	2,948.87
Annual meeting: registration fees, exposition space, advertising in program, and contributions	41,906.31
Income from investment of funds not needed in checking account	8,489.56
Rental income from third floor and garage of new building	11,350.65
Allowance for expenses incurred in administering grants	16,820.61
Miscellaneous receipts	1,478.15
Total	$719,233.81

These receipts amounted to $1227.96 more than the operating expenses. This amount, therefore, was the association's surplus for the year. The principal items of expense were

Printing and editing *Science* and *The Scientific Monthly*	$378,161.95
Editorial Board expenses and honoraria	6,422.17
Cost of selling advertising in the two journals	54,506.96
Printing and editing symposium volumes	21,807.12
Cost of emblems, binders, Microcards	1,735.26
Meetings of boards and committees	11,098.65
Contribution to Scientific Manpower Commission	1,000.00
Recruitment of new members (exclusive of salaries)	9,109.51
Expenses of the annual meeting	34,365.44
Press service for annual meeting	4,901.56
Allowances ($1 per member) to Pacific, Southwestern and Rocky Mountain, and Alaska Divisions	7,772.00
Expenses of AAAS sections	5,303.69
Administrative staff salaries and general expenses	121,950.28
Rental of temporary quarters during construction of new building	7,613.00
Building maintenance	23,744.60
Real estate taxes	9,643.05
Depreciation of building	13,691.40
Depreciation of furniture and equipment	2,796.58
Miscellaneous other expenses	2,379.63
Total	$718,005.85

Comparison of 1956 with 1955

Receipts in 1956 were $116,813.13 above those for 1955. Over half of the increase was derived from advertising in *Science*, $61,231. Other increases were noted in annual dues, $17,195; the New York meeting as compared with that in Atlanta, $14,435; increased activity in administering grants, $13,439; rental from the new building in excess of rental from the old residential buildings, $10,272; and nonmember subscriptions, $5439.

Current expenses in 1956 were greater by $124,329 than they were in 1955. The largest increases were in the cost of housing the association's offices, the cost of publishing the association's journals, administrative expenses, and the cost of securing advertisements. The cost of renting office space during part of the year and of maintaining the new building, including real estate tax and depreciation, resulted in increased expenses of $35,105. Printing and editing *Science* and *The Scientific Monthly* cost $33,744 more in 1956 than in 1955. Administrative and general expenses were $22,635 higher in 1956, and it cost $18,405 more to solicit advertising in the association's journals .

Investment Account

To keep them separated from current funds and grants for special activities, the association holds its endowment and investment funds in a separate Investment Account. Although the association has some leeway in the handling of these funds, ordinarily the income is used and the principal left intact. Disbursements during 1956 were as follows.

Income allocated to Gordon Research Conferences	$ 1,624.47
Transfer to Gordon Research director's fund	10,000.00
Newcomb Cleveland prize	1,000.00
Socio-psychological prize and expense	1,016.41
Grants to academies of science to use in support of research	4,371.00
Transferred to operating account to pay for journal subscriptions for emeritus and life members	3,568.50
Expenses of managing investments	1,794.97

The accompanying statement of receipts and disbursements from this account also shows that $119,704 was spent for the purchase of securities. This amount was derived from the sale of other securities, $99,884; from a payment from the estate of Margaret Smith Young, $11,811; from life membership fees, $3488; and in part from the investment income of $23,766.

At the end of 1956 the Investment Account showed assets of $451,368, of which $26,502 consisted of endowment for the Gordon Research Conferences and $424,865 was for the other purposes mentioned in the first paragraph of this report. The funds in the Investment Account were distributed as follows.

	Book value	*Market value*
Cash	$ 12,542.26	$ 12,542.26
U.S. Government bonds	76,237.50	70,680.00
Other bonds	116,082.95	107,350.00
Preferred stocks	58,908.59	51,320.00
Common stocks	187,597.21	269,955.00
Total	$451,368.51	$511,847.26

Consolidated Balance Sheet

In order to give a view of the association's financial position, the figures from the Current Fund and Investment Account have been combined here. At the end of 1956, the consolidated balance sheet showed the following assets.

Cash	$ 147,315.17
Money owed to the Association	35,433.99
Money invested in securities	804,783.40
Value of new building and land	886,155.46
Value of new furniture and equipment	46,690.84
Total	$1,920,378.86

Offsetting these assets, as they always must in a balance sheet, were liabilities, as shown in the following list.

Accounts payable to others	$ 115,408.37
Unexpended portions of grants from Carnegie Corporation, National Science Foundation, and General Electric Educational and Charitable Fund	101,067.37
1957 dues and subscriptions received, but for which members and other subscribers had not yet received journals or other services	300,867.75
Mortgage payable in 9.5 years	167,503.46
Endowment funds for prizes, research grants, life and emeritus members' subscriptions, and general purposes	421,555.75
Building fund (contributions and earlier surplus invested in the association's building)	718,652.00
Unallocated funds	95,324.16
Total	$1,920,378.86

Grants Received in 1956

Among the liabilities shown is an item of $101,067 which represented the unexpended portions of grants made to the association. The grants received are briefly accounted for in the following paragraphs.

From the Carnegie Corporation, the Association received $100,000 on 1 July 1956. This amount was the second payment of a grant of $300,000 to support the AAAS Science Teaching Improvement Program. In addition, $88,337 was available representing the unexpended balance as of 1 Jan. 1956.

During the year, a total of $130,184 was paid out for this program—including $77,085 to four centers for the study of the use of science counselors. The unexpended balance on 31 Dec. was $58,153.

For Conferences on Mathematics Instruction, the association received $6000 from the Carnegie Corporation. The unexpended balance on 31 Dec. was $4240.

The General Electric Educational and Charitable Fund granted the association $12,000 for a program for Regional Consultants on Science and Mathematics. The balance on 31 Dec. was $10,267.

The National Science Foundation followed up its 1955 grant during 1956 with a payment of $65,100 to continue on a larger scale the project of Traveling High-School Science Libraries. The balance on 1 Jan. had been $8946. On 31 Dec. there remained on hand $28,406.

Auditor's Report

A condensed statement of the association's finances for 1956, prepared by the firm of G. P. Graham and Company, is published herewith. Balance sheets and statements of receipts and expenditures are given separately for the Current Fund and the Investment Account. The portion of the auditor's report published here does not include funds for the Gordon Research Conferences. The conferences, after a continuous existence for 25 years, were incorporated as a separate unit during 1956.

HANS NUSSBAUM

Business Manager, AAAS

25 June 1957

To the Council of the
American Association for the Advancement of Science
Washington, D.C.

We have examined the balance sheet of the Current Fund of the American Association for the Advancement of Science as at 31 Dec. 1956, and the statement of revenue and expenditures for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statements present fairly the financial position of the Current Fund of the American Association for the Advancement of Science as at 31 Dec. 1956, and the results of its operations for the year then ended.

G. P. GRAHAM & COMPANY
By G. R. BOWERS

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE CURRENT FUND

BALANCE SHEET, AS AT 31 DEC. 1956

Assets

Cash on deposit			$ 131,272.91
Imprest funds			3,075.00
Accounts receivable			35,433.99
Deposit with airline			425.00
Investments			392,459.90
Land			115,875.00
Building		$783,971.86	
Less allowance for depreciation		13,691.40	770,280.46
Furniture and equipment		$ 49,487.42	
Less allowance for depreciation		2,796.58	46,690.84
			$1,495,513.10

Liabilities and net worth

Accounts payable			$ 112,098.36
Unexpended balances of grants			
High school libraries		$ 28,406.27	
Science teaching improvement program		58,153.05	
Conference on mathematics instruction		4,240.55	
Regional consultants on science and mathematics teaching program		10,267.50	101,067.37
Deferred income			
Prepaid dues		$239,202.43	
Prepaid subscriptions		61,665.32	300,867.75
Mortgage payable			167,503.46
Reserve fund			250,000.00
Unallocated funds			
Balance 1 Jan. 1956		$368,853.83	
Add: Excess of revenue over expenditures	$ 1,227.96		
Building fund	193,894.37	195,122.33	
Balance 31 Dec. 1956			563,976.16
			$1,495,513.10

American Association for the Advancement of Science Current Fund

Statement of Revenue and Expenditures for the Year Ended 31 Dec. 1956

Revenue			
Dues			$ 306,003.52
Journals			
Subscriptions			
From investment account (life, 50-year and emeritus members)	$ 3,568.50		
Members special subscriptions	22,237.15		
Nonmember subscriptions	66,065.03	$ 91,870.68	
Advertising		214,883.28	
Miscellaneous		2,466.96	309,220.92
Publications			
Binders		$ 1,050.52	
Symposium volumes		21,015.22	22,065.74
New York meeting and exposition			41,906.31
Income from investments			8,489.56
Rental income			11,350.65
Miscellaneous			20,197.11
			$ 719,233.81
Expenditures			
Administrative and general expense		$ 45,766.36	
Business office		76,183.92	
Building expenses		33,387.65	
Rental of temporary offices		7,613.00	
Depreciation—building and equipment		16,487.98	
Board of directors		6,537.61	
Other committees		4,561.04	
Allowance to divisions		7,772.00	
Section expense		5,303.69	
Circularization—new members		9,109.51	
Annual meeting and exposition		39,267.00	
Journals		439,094.08	
Publications		22,377.40	
Miscellaneous		4,544.61	$ 718,005.85
Excess of revenue over expenditures			**$ 1,227.96**

To the Council of the
American Association for the Advancement of Science
Washington, D.C.

25 June 1957

We have examined the balance sheet of the Investment Account of the American Association for the Advancement of Science as at 31 Dec. 1956, and the statement of cash receipts and disbursements for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as are considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial position of the Investment Account of the American Association for the Advancement of Science as at 31 Dec. 1956, and the cash receipts and disbursements for the year then ended.

G. P. Graham & Company
By G. R. Bowers

American Association for the Advancement of Science Investment Account

Balance Sheet as at 31 Dec. 1956

Assets

Cash in bank		$ 12,542.26
Securities—at cost		412,323.50
		$424,865.76

Liabilities and reserves

Liabilities		
Academy grants	$ 3,185.01	
Special academy grants	125.00	$ 3,310.01
Endowment funds		
For research	$179,778.85	
For general purposes	173,618.80	
For special purposes	68,158.10	421,555.75
		$424,865.76

American Association for the Advancement of Science Investment Account

Statement of Cash Receipts and Disbursements for the Year Ended 31 Dec. 1956

Cash balance 1 Jan. 1956		$ 16,334.46
Receipts		
Income from investments	$ 23,766.29	
Redemption and sale of securities	99,884.24	
Life membership fees	3,788.50	
Gifts	11,811.04	
Special academy grants	400.00	
Deceased emeritus life membership fees	1,100.00	140,750.07
		$157,084.53
Disbursements		
Accounts payable	$ 62.00	
Income allocated to Gordon Research Conferences	1,624.47	
Transfer to Gordon Research Conferences	10,000.00	
Securities purchased	119,704.92	
Newcomb Cleveland prize	1,000.00	
Socio-psychological prize and expense	1,016.41	
Academy grants	3,621.00	
Special academy grants	750.00	
Emeritus life membership fees (from Jane M. Smith fund)	300.00	
Deceased emeritus life membership fees (to Jane M. Smith fund)	1,100.00	
Journal subscriptions, (life, 50-year and emeritus members)	3,568.50	
Expenses	1,794.97	144,542.27
Cash balance 31 Dec. 1956		**$ 12,542.26**

(*Continued from page 215*)

Comprehensive Inorganic Chemistry. vol. 6. *The Alkali Metals.* John F. Suttle. *Hydrogen and Its Isotopes.* Robert C. Brasted. Van Nostrand, Princeton, N.J., 1957. 242 pp. $6.

The Logical Problem of Induction. Georg Henrik von Wright. Macmillan, New York, ed. 2, 1957. 261 pp. $4.

Organic Chemistry. Louise Kelley. McGraw-Hill, New York, ed. 2, 1957 (ed. 1 by G. Albert Hill and Louise Kelley). 765 pp. $7.50.

Radioastronomie. Raymond Coutrez. Edition du Patrimoine de l'Observatoire Royal de Belgique, Uccle, 1956. 391 pp. F. 250.

The Biological Action of Growth Substances. Symposia of the Society for Experimental Biology, No. XI Academic Press, New York, 1957. 351 pp. $9.50.

Introduction to Electrical Applied Physics. N. F. Astbury. Philosophical Library, New York, 1957. 252 pp. $10.

The Demand and Supply of Scientific Personnel. David M. Bland and George J. Stigler. National Bureau of Economic Research, New York, 1957. 219 pp. $4.

The American Teenager. H. H. Remmers and D. H. Radler. Bobbs-Merrill, Indianapolis, Ind., 1957. 267 pp. $3.75.

Analytical Microscopy. Its aims and methods in relation to foods, water, spices, and drugs. T. E. Wallis. Little, Brown, Boston, Mass., ed. 2, 1957. 215 pp. $5.50.

The Making of a Moon. The story of the earth satellite program. Arthur C. Clarke. Harper, New York, 1957. 205 pp. $3.50.

One Man's Life with Barley. The memories and observations of Harry V. Harlan. Exposition Press, New York, 1957. 223 pp. $6.

Geologic Field Methods. Julian W. Low. Harper, New York, 1957. 504 pp. Professional edition, $6; text edition, $4.50.

The Caricature of Love. A discussion of social, psychiatric, and literary manifestations of pathologic sexuality. Hervey Cleckley. Ronald, New York, 1957. 329 pp. $6.50.

Hospital Treatment of Alcoholism. A comparative, experimental study. Menninger Clinic monograph ser. No. 11. Robert S. Wallerstein and others. Basic Books, New York, 1957. 223 pp. $5.

Antarctic Hazard. Ross Cockrill. Philosophical Library, New York, 1957. 230 pp. $4.75.

An Approach to Modern Physics. E. N. da C. Andrade. Doubleday, Garden City, N.Y., 1957. 266 pp. Paper, $0.95.

Basic Mathematics for Radio and Electronics. F. M. Colebrook and J. W. Head. Iliffe, London; Philosophical Library, New York, ed. 3, 1957. 359 pp. $6.

Beyond Freud. A creative approach to mental health. Camilla M. Anderson. Harper, New York, 1957. 288 pp. $4.

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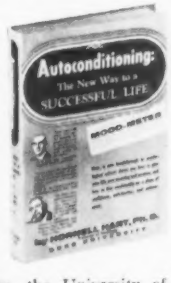

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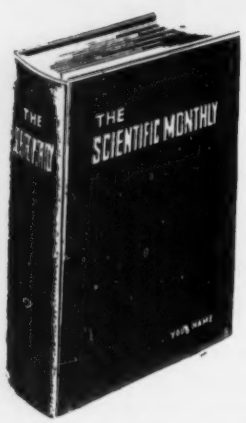

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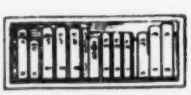

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Meetings

November

2–8. World Metallurgical Cong., 2nd, Chicago, Ill. (W. H. Eisenman, American Soc. for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.)

2–10. Measuring Instruments and Automation, intern. cong., Düsseldorf, Germany. (Nordwest Deutsche Ausstellungs Gesellschaft, M.B.H., Ehrenhof 4, Düsseldorf.)

3. American College of Dentists, annual, Miami, Fla. (O. W. Brandhorst, 4221 Lindell Blvd., St. Louis 8, Mo.)

3. Society of Vertebrate Paleontology, annual, Philadelphia, Pa. (J. T. Gregory, Peabody Museum, Yale Univ., New Haven, Conn.)

3–9. Pan American Cong. of Pharmacy and Biochemistry, 4th, Washington, D.C. (G. Griffenhagen, Smithsonian Institution, Washington 25.)

4–5. Crystal Structure Analysis by IBM 704 Computer, NBS Conf., Washington, D.C. (V. Vand, Pennsylvania State Univ., University Park.)

4–5. Society of Vertebrate Paleontology, technical sessions, Atlantic City, N.J. (J. T. Gregory, Peabody Museum, Yale Univ., New Haven, Conn.)

4–6. Analytical Chemistry in Nuclear Reactor Technology, Gatlinburg, Tenn. (D. D. Cowen, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn.)

4–6. Geological Soc. of America, annual, Atlantic City, N.J. (H. R. Aldrich, GSA, 419 W 117 St., New York 27.)

4–6. Mineralogical Soc. of America, annual, Atlantic City, N.J. (C. S. Hurlbut, Jr., Dept. of Mineralogy, Harvard Univ., Cambridge 38, Mass.)

4–6. Paleontological Soc., annual, Atlantic City, N.J. (H. B. Whittington, Museum of Comparative Zoology, Harvard Univ., Cambridge 38, Mass.)

4–6. Society of Economic Geologists, annual, Atlantic City, N.J. (H. M. Bannerman, U.S. Geological Survey, Washington 25, D.C.)

4–7. American Dental Assoc., annual, Miami, Fla. (Harold Hillenbrand, 222 E. Superior St., Chicago 11, Ill.)

6–8. Electronic Techniques in Medicine and Biology, Boston, Mass. (H. S. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh 22, Pa.)

7–8. Society for Applied Spectroscopy, 12th annual, New York, N.Y. (J. Hansen, 27 Tulsa Ave., Metuchen, N.J.)

7–8. Television and Radio in the Health Field, conf., Chicago, Ill. (American Medical Assoc., 535 N. Dearborn St., Chicago 10.)

7–9. Animal Care Panel, 8th annual, San Francisco, Calif. (R. J. Flynn, ACP, Box 299, Lemont, Ill.)

7–9. Society of Rheology, annual, Princeton, N.J. (W. R. Willets, Titanium Pigment Corp., 99 Hudson St., New York 13.)

10–13. Society of American Foresters, 57th annual, Syracuse, N.Y. (Henry Clepper, SAF, 415 Mills Bldg., Washington 6, D.C.)

10–13. Xi Sigma Pi, Syracuse, N.Y. (J. R. Parker, School of Forestry, Univ. of Georgia, Athens.)

10–14. Society of Exploration Geophysicists, 27th annual, Dallas, Tex. (J. C. Hollister, Colorado School of Mines, Golden.)

11–13. Radio Fall Meeting, IRE, Toronto, Ont., Canada. (V. Graham, RETMA, 11 W. 42 St., New York 26.)

11–14. American Petroleum Inst., 37th annual, Chicago, Ill. (API, 50 W. 50 St., New York 20.)

11–15. American Public Health Assoc., 85th annual, Cleveland, Ohio. (R. M. Atwater, APHA, 1790 Broadway, New York 19.)

11–15. American Soc. of Professional Biologists, annual, with American Public Health Assoc., Cleveland, Ohio. (A. F. Borg, Dept. of Bacteriology, Kansas State College, Manhattan.)

13–15. American Meteorological Soc., College Station, Tex. (K. C. Spengler, AMS, 3 Joy St., Boston 8, Mass.)

13–15. Clinical Chemistry Symp., Cleveland, Ohio. (Frank E. Bunts Educational Inst., Cleveland Clinic Foundation, 2020 E. 93 St., Cleveland 6.)

13–15. Standards, 8th natl. conf., San Francisco, Calif. American Standards Assoc., 70 E. 45 St., New York 17.)

13–16. Society of Naval Architects and Marine Engineers, 65th annual, New York. (W. N. Landers, SNAME, 74 Trinity Pl., New York 6.)

14–15. Operations Research Soc. of America, Pittsburgh, Pa. (M. L. Ernst, Box 2176, Potomac Station, Alexandria, Va.)

14–16. American Inst. of Mining, Metallurgical, and Petroleum Engineers, semiannual, Chicago, Ill. (H. N. Appleton, AIME, 29 W. 39 St., New York 18.)

14–16. American Soc. of Refrigerating Engineers, Chicago, Ill. (R. C. Cross, ASRE, 234 Fifth Ave., New York 1.)

17–22. Radiological Soc. of North America, annual, Chicago, Ill. (D. S. Childs, 713 E. Genesee St., Syracuse, N.Y.)

18–21. Magnetism and Magnetic Materials Conf., Washington, D.C. (L. R. Maxwell, U.S. Naval Ordnance Lab., White Oak, Silver Spring, Md.)

18–22. American Soc. of Agronomy, annual, Atlanta, Ga. (L. G. Monthey, ASA, 2702 Monroe St., Madison, Wis.)

18–22. Citrus Virus Diseases Conf., Riverside, Calif. (J. M. Wallace, Dept. of Plant Pathology, Univ. of California, Riverside.)

18–9. Pacific Science Cong., 9th, Bangkok, Thailand. (Pacific Science Board, National Research Council, 2101 Constitution Avenue, NW, Washington 25, D.C.)

20–24. National Assoc. for Mental Health, annual, Atlantic City, N.J. (NAMH, 10 Columbus Circle, New York 19.)

25–27. American Academy for Cerebral Palsy, 11th annual, New Orleans, La. (R. R. Rembolt, Iowa Hospital-School, State University of Iowa, Iowa City.)

25–27. Physics and Dynamics of Fluids, APS, Bethlehem, Pa. (F. N. Frenkiel, Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.)

28–30. Central Assoc. of Science and Mathematics Teachers, 57th annual, Chicago, Ill. (L. Panush, Northeastern High School, Detroit 7, Mich.)

29–30. American Physical Soc., St. Louis, Mo. (K. K. Darrow, Columbia Univ., New York 27.)

29–30. American Soc. of Animal Production, annual, Chicago, Ill. (H. H. Stonaker, Animal Husbandry Dept., Colorado State Univ., Fort Collins.)

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7. Titles of the latest foreign and domestic scientific films to be shown in the AAAS Science Theatre.
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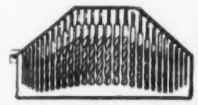

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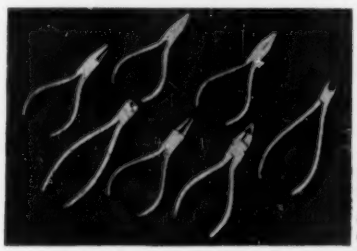

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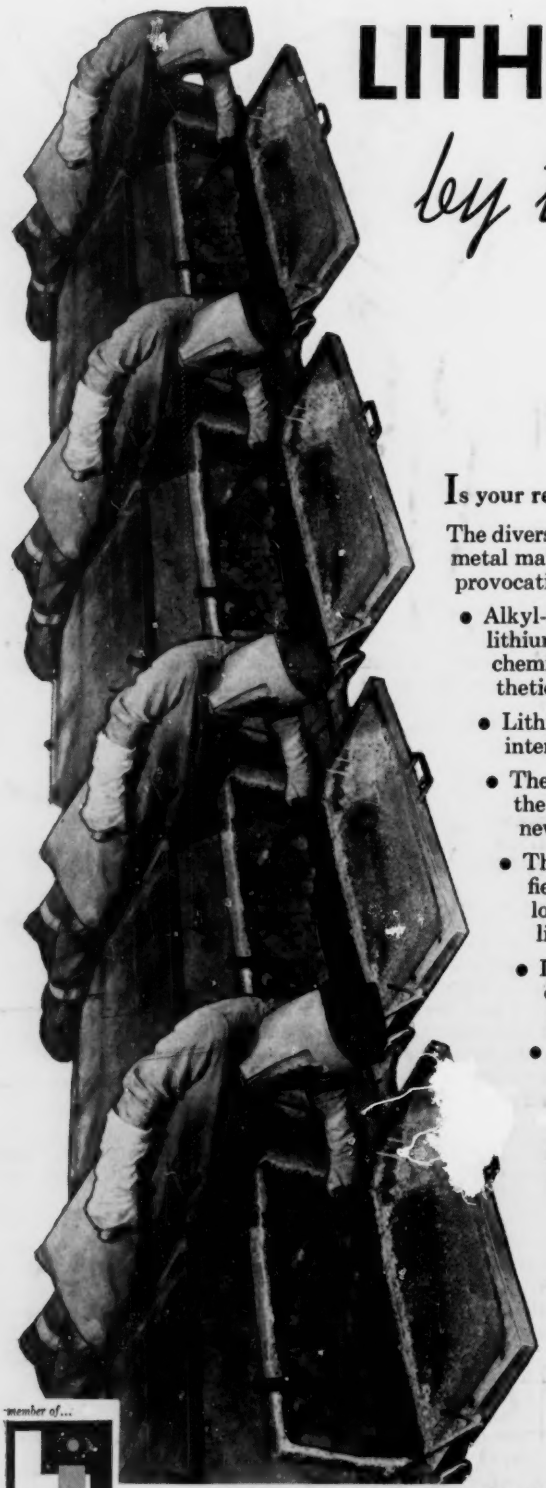

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